Uppsala 1969

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The Elderly Patient after Anaesthesia and Surgery

With Special Regard to Certain
Respiratory, Circulatory, Metabolic
and Muscular Functions

Universitetsforlaget i Aarhus

This work is also published as Supplementum XXXIV, 1969,
to Acta anaesthesiologica Scandinavica

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THE ELDERLY PATIENT AFTER ANAESTHESIA AND SURGERY

With Special Regard to Certain Respiratory, Circulatory, Metabolic and Muscular Functions

By

HANS RENCK

1969 - SUPPLEMENTUM XXXIV

UNIVERSITETSFORLAGET I AARHUS

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PRINTED IN DENMARK BY AARHUUS STIFTSBOGTRYKKERIE A/S

THE ELDERLY PATIENT AFTER ANAESTHESIA AND SURGERY

With Special Regard to
Certain Respiratory, Circulatory, Metabolic
and Muscular Functions

AKADEMISK AVHANDLING

som med vederbörligt tillstånd av
Medicinska fakulteten vid Uppsala Universitet
för vinnande av medicine doktorsgrad
framlägges till offentlig granskning å
Kirurgiska klinikens föreläsningssal
lördagen den 26 april 1969
kl. 9 f. m.

av
HANS RENCK
med. lic.

UPPSALA 1969

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CONTENTS

Symbols and Notations 5

General Introduction 9

Part I.

Respiratory, Circulatory and Metabolic Changes After Prostatectomy in Relation to Age and Preoperative Status, Type of Anaesthesia and Blood Loss

Chapter 1, Outline, Material and Methods 13

1.1 Aim of the investigation 13
1.2 Material 13
1.3 Clinical management 13
1.3.1 Surgery (by Anders Engberg M.D.) 13
1.3.2 Anaesthesia 15
1.3.3 Postoperative management 16
1.3.4 Fluid supply 16
1.4 Investigation programme 17
1.5 Methods 18

Chapter 2, Results 23

2.1 General results 23
2.2 Results related to age 25
2.3 Results related to preoperative ventilatory function 26
2.4 Results related to preoperative physical working capacity 27
2.5 Results related to type of anaesthesia 27
2.6 Results related to adequately replaced per- and postoperative blood loss . . . 39

Chapter 3, Discussion 42

3.1 Preoperative condition of the patients 43
3.2 Postoperative changes 44

Chapter 4, Clinical Implications 56

Chapter 5, Summary 59

Part II.

Isometric Muscle Strength and Physical Working Capacity After Prostatectomy in Relation to Preoperative Status and Postoperative Course

Chapter 6, Outline Material and Methods 63

6.1 Aim of the investigation 63
6.2 Material 63
6.3 Postoperative management 64
6.4 Complications 64
6.5 Methods 65

Chapter 7, Results 68
7.1 General results 68
7.2 Relationship of preoperative status and per- and postoperative course to changes of muscle strength and physical working capacity 71

Chapter 8, Discussion 74
8.1 Evaluation and validity of the results 74
8.2 Isometric muscle strength 75
8.3 Physical working capacity 77

Chapter 9, Clinical Implications 83

Chapter 10, Summary 85

Acknowledgements 87

References 88

Tables 95

SYMBOLS AND NOTATION

Examination occasions (ex.):

I = 1–5 days preoperatively
II = Preoperatively, day of operation
OP = Peroperatively during suturing of the bladder
III = About 15 min postoperatively
IV = About 17 hours postoperatively
V = Before discharge of the patient from hospital, usually 12–14 days postoperatively
VI = 5–7 months postoperatively

Groups of patients:

A = *A*bove average with respect to the following subscripts
B = *B*elow average with respect to the following subscripts
- age = age of patient
- bl = blood loss
- cath = duration of postoperative catheterization
- ecg = electrocardiogram
- ecg chd = ecg indicating coronary heart disease
- ecg p = non-specific pathological ecg
- ox = immediately postoperative oxygen transport situation
- temp = postoperative elevation of rectal temperature
- w = preoperative physical working capacity
- vent = preoperative ventilatory capacity

H = ○ = Pentothal®-O_2-N_2O-halothane anaesthesia with spontaneous ventilation
C = □ = Pentothal®-O_2-N_2O-d-Tubocurarine anaesthesia with mechanically controlled ventilation, reversed with atropine and neostigmine
S = △▽ = Spinal nerve block in the form of either:
Ss = △ = subarachnoid anaesthesia, or
Se = ▽ = epidural anaesthesia

General notation:

A-aD = Alveolo-arterial tension gradient, mm Hg
AVD_{O_2} = Arterio-venous oxygen difference, ml/100 ml blood
B.E. = Base excess, mEq/l
$\overline{BP}$ = Mean arterial blood pressure, mm Hg
BP = Arterial blood pressure, mm Hg
BTPS = Body temperature and pressure, saturated with water vapour
BW = Body weight, kg
$\dot{C}a_{O_2}$ = Available oxygen, ml/min
C_{O_2} = Oxygen content, ml/100 ml blood
F = Fraction, vol/vol per cent
f = respiratory rate, breaths per minute
$FEV_{1,0}$ = Forced expired volume in one second
Hb = Haemoglobin concentration, g/100 ml blood
HCO_3^- = standard bicarbonate, mEq/l
Hct = haematocrit, per cent
HR = heart rate, beats per minute

$HR \times \overline{BP}$ = pulse-blood pressure product (estimated under certain conditions to be roughly related to heart work), units
$HR_{log\ lact}$ = calculated HR at lact = 5 mEq/l, beats per minute
I_{musc} = muscular strength index, per cent of preoperative value
lact = lactate concentration, mEq/l
log lact 130 = logarithm for the calculated lact in mEq/l at HR = 130
nm = nanometer, 10^{-9} m
O_2uc = oxygen utilization coefficient, per cent
P = gaseous tension, mm Hg
PEF = peak expiratory flow, l/min
$\dot{Q}$ = effective cardiac output, l/min
$\dot{Q}s/\dot{Q}t$ = shunt blood flow/cardiac output ratio
R = respiratory exchange ratio
S = saturation, per cent
STPD = standard temperature and pressure, dry
TBV = total blood volume, l
THb = total amount of haemoglobin, g
t_{rect} = rectal temperature, °C
$\dot{V}_A$ = alveolar ventilation, l BTPS/min
$\dot{V}_A/\dot{Q}$ = average ventilation—perfusion ratio, l BTPS/l
VC = vital capacity
V_D = physiological dead space, ml BTPS
V_D/V_T = physiological dead space/tidal volume ratio, per cent
$\dot{V}_E$ = pulmonary ventilation, l BTPS/min
$\dot{V}_{O_2}$ = oxygen uptake, ml STPD/min. m^2 BSA
V_T = tidal volume, ml BTPS
W_{lact} = work load, kpm/min performed at lact = 5 mEq/l
$W_{max.\ perf}$ = maximum performed work load, kpm/min
W_{130} = work load, kpm/min, performed at HR = 130 during exercise test
1 = horizontal pull, kp
2 = horizontal push, kp
24 = knee flexion, kpcm
25 = knee extension, kpcm
30 = forward flexion of the trunk, kp
31 = backward extension of the trunk, kp

Prefix :

d = $\triangle$ = Relative change value, given in relation to the preoperative value, generally in per cent

Subscripts :

A = alveolar
$\bar{A}$ = mixed alveolar
a = arterial
aw = ten minutes after work
b = barometric pressure
c = pulmonary end-capillary
dx = right
E = expiratory
I = inspiratory
max = maximal or maximum
max. obs = maximum observed
ort = after eight minutes' passive standing

rest = after ten minutes' supine rest
sin = left
$\bar{v}$ = mixed venous
work = during submaximal work

Statistical notation :

n = number of patients

$$M = \frac{\Sigma x_i}{n} = \text{mean value, where } x_i \text{ denotes the i-th recorded value in a serie of n values}$$

$$SD = \sqrt{\frac{n\Sigma x^2 - (\Sigma x)^2}{n\,(n-1)}} = \text{standard deviation}$$

$$SEM = \frac{SD}{\sqrt{n}} = \text{standard error of the mean}$$

$$t = \frac{M}{SEM} = \text{critical ratio where the number of degrees of freedom are } n - 1$$

D = difference in comparison between two groups

$$= \frac{M_x - M_y}{\sqrt{\frac{SD_x^2}{n_x} + \frac{SD_y^2}{n_y}}}$$

P = probability
S = significance
NS = denotes a non-significant difference; $P > 0.05$
x = denotes a (probably) significant difference; $0.01 < P \leq 0.05$
xx = denotes a significant difference; $0.001 < P \leq 0.01$
xxx = denotes a (highly) significant difference; $P \leq 0.001$

GENERAL INTRODUCTION

In recent years, surgical operations on elderly patients have increased, absolutely as well as relatively. Many surveys relevant to these problems have been made (e.g. [3, 28, 67, 98, 103, 111]).

From an anaesthesiological point of view, the main problems of clinical interest in this connection concern the oxygen transport situation in the immediate postoperative period. At this time the patient's vital functions are not always so closely supervised as during the operation, and consequently, aid on deterioration of these functions is not always so promptly provided. Postoperatively, the oxygenation and circulation are still depressed by various effects of anaesthesia and surgery and the patient is sometimes restricted at this time to an environment of atmospheric air. Especially in elderly persons, with their reduced respiratory ([11, 25, 93, 99, 109]) and circulatory ([9, 38, 104, 127, 136]) functions—in clinical practice often exaggerated by the effects of pathological changes in the cardiopulmonary system—there would seem to be a predisposition for inadequate oxygenation of the tissues. Hypoxia can result in irreversible damage to the central nervous system and to the myocardium. Postoperative damage to the myocardium in elderly patients has been reported by Walker & Macdessi (1966)[138], and signs of impaired mental capacity by Bedford (1955)[13] and McMichael (1958)[86]. For these reasons these authors advise against elective surgery, based on wide indications, on elderly patients. In a later study which included mental testing, Simpson et al. (1961)[118] found an overall benefit of elective surgery on people of advanced age. In Scandinavia the indications for surgery on elderly patients have remained unchanged during the last 10–15 years (Antila et al., 1966)[5], or widened (Renck, 1965[103], Holmdahl et al., 1966[67]).

The expression "operability" as it is generally used in preoperative assessments of elderly patients, should comprise an estimate not only of the possibility of treating an illness by surgery, but also of the potentialities of the patient to fulfil the demands on the oxygen transport system raised by anaesthesia and surgery, and to recover promptly from anaesthesia and surgery, essentially without complications and preferably with unchanged or improved vital functions.

The present study was undertaken to elucidate these problems. As an anaesthesiologist, the author was especially interested in the respiration, circulation and metabolism during recovery from different types of anaesthesia. For this purpose three different types of anaesthesia were chosen, namely one with maintained spontaneous ventilation and a potent inhalational anaesthetic

agent (Halothane), one with controlled ventilation and no potent anaesthetic agent (O_2-N_2O-d-Tubocurarine), and one type without general anaesthesia (spinal nerve block).

The complete investigation programme is presented in Table 1. No homogeneous geriatric surgical series appears to have been subjected to such analyses previously.

Part I

Respiratory, circulatory and metabolic changes after prostatectomy in relation to age and preoperative status, type of anaesthesia, and blood loss

Chapter 1

OUTLINE, MATERIAL AND METHODS

1.1 AIM OF THE INVESTIGATION

Elderly patients were examined after similar operations, with regard to changes in the oxygen uptake, ventilation, oxygenation of arterial blood, circulation and the acid-base balance in arterial blood, as compared with the corresponding preoperative values. The principal aim of the investigation was to correlate these changes with (1) the age of the patient, (2) the preoperative ventilatory state, (3) the preoperative circulatory state, (4) some common forms of anaesthesia and (5) blood loss, adequately replaced.

1.2 MATERIAL

The series consisted of 86 men who were subjected to prostatectomy at the surgical clinic of the University Hospital in Uppsala during the period September 1965 to January 1968. Figure 1 presents the series in relation to the total number of patients subjected to transvesical prostatectomy during the corresponding period. Some characteristics of the series are given in Table 2.

The principles followed in selecting the patients for surgery are given in section 1.3.1. All patients of 60 years of age and older who presented clear surgical indications for prostatectomy and who were considered medically fit for the investigation programme were asked whether they were willing to take part in the investigation. No patient refused to participate. Patients showing pronounced signs and symptoms of cardiac failure or pulmonary insufficiency, and patients showing considerable cerebral abnormality, malignant disease or greatly reduced vision or hearing were excluded. In general, these patients were not operated on.

The examination capacity was only one new patient per week, which meant a certain selection during periods of a good supply of patients. On such occasions the oldest patient was generally selected for the investigation.

1.3 CLINICAL MANAGEMENT

1.3.1. Surgery (by Anders Engberg, M. D.)

Selection of patients for surgery. The urologic investigation included rectal palpation, measurement of residual urinary volume, intravenous pyelography and renal function tests (creatinine in serum and urinary specific gravity or osmolality). In almost every case

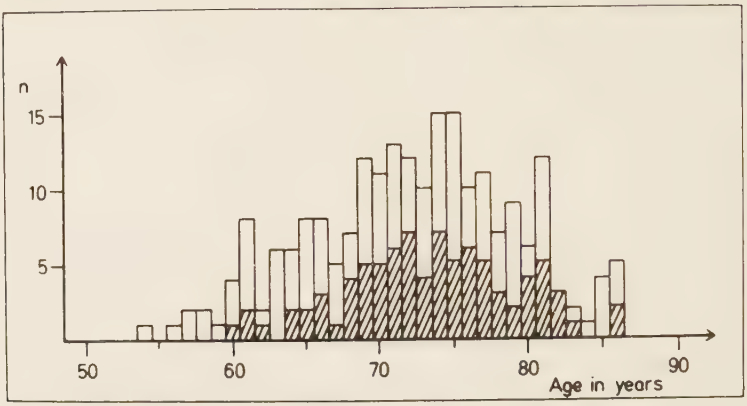

FIG. 1.—Distribution of the patients in the series according to age (////). Patients submitted to transvesical prostatectomy in this clinic during the same period but not included in the present series, are also shown (□).

the lower urinary tract was examined with a urethrocystoscope, with simultaneous palpation of the prostate gland.

The operative technique used was transvesical enucleation of the prostatic adenomas. To be considered suitable for this type of operation the patients should have a normal renal function and significant bladder obstruction caused by a considerable benign prostatic enlargement.

Operative technique. The urinary bladder was approached through a low midline incision without opening the peritoneal cavity. The bladder was incised at the vertex. To allow careful inspection of the bladder the lowest part of the bladder incision was temporarily sutured to the distal corner of the abdominal incision. The mucosa around the internal urethral meatus was incised by diathermy and the prostatic adenomas were enucleated with the index finger. To visualize the ureteric orifices a brisk diuresis was induced by intravenous infusion of 200 ml of 15 per cent Mannitol (Mannidex®). Haemostatic sutures then were placed in the dorsal lateral corners of the internal urethral meatus, taking fairly large bites of the bladder wall and the prostatic capsule. Additional bleeding points were secured by direct suture. In the majority of patients the posterior bladder neck was partly excised and the bladder mucosa sutured directly to the prostatic capsule. Resection of the posterior bladder neck was omitted only when the internal meatus was very wide and had no posterior wall. Bladder drainage was accomplished by means of Couvelaire catheters, one (French no. 20–22) through the urethra and the other (French no. 24) through a separate incision in the bladder and the abdominal wall. The bladder was sutured in two layers with continuous plain catgut and the abdominal incision with interrupted sutures in the fascia and skin. No prophylactic resection of the vas deferens was performed. When the operation was completed the urethral catheter was fixed to the skin in one of the groins. This was done to minimize catheter damage to the urethra in the penoscrotal angle. To avoid an accumulation of clots the bladder was flushed continuously with Cystosol® during 12–24 hours. The flushing system was closed and evacuation was facilitated by a continuous mild suction (−3 to −5 cm H_2O).

Additional procedures. In seven cases additional surgical procedures were undertaken to control excessive bleeding. These procedures included gauze tamponade of the prostatic bed (4 cases), bilateral ligation of the internal iliac arteries (1 case) and gauze tamponade of the prostatic bed + bilateral ligation of the internal iliac arteries + temporary urinary diversion by low bilateral ureterostomies (2 cases).

1.3.2. Anaesthesia

All the anaesthetics were supervised by the author.

Premedication with 0.5 mg of atropine and 50 mg of promethazine was given to all patients.

Three main types of anaesthesia were used:

a) *Pentothal®-O_2-N_2O-halothane, spontaneous ventilation* (*H*). For at least 2 min prior to induction of anaesthesia the patients breathed 100 per cent O_2 in a partial rebreathing system without CO_2 absorption[1]) (Magill's attachment) with an oxygen flow exceeding 10 liters per minute. The composition of the inhaled gas was then changed to 3 liters O_2 + 5 liters N_2O per min. At the same time 150 mg of Pentothal® followed by 50–75 mg of succinyl choline were given intravenously. The patients were intubated with a cuffed tube.[2])

The ventilation was controlled manually until neuromuscular transmission returned, after which the patients breathed spontaneously. On resumption of spontaneous breathing, halothane was given in concentrations varying between 0.5 and 1.5 per cent.[3]) The level of anaesthesia was adjusted according to the demands of surgery and the reaction of the blood pressure. The aim was always to obtain a practically normotensive anaesthesia. In certain cases 25 mg doses of meperidine, maximal total 50 mg, were added for rapid increase of depth of anaesthesia.

When the oxygen concentration in the inhaled gas had been increased to 100 per cent and the oral cavity, pharynx and trachea had been cleared by suction, the orotracheal tube was removed. Extubation took place during residual anaesthesia in order to avoid laryngospasm. 100 per cent O_2 was then insufflated, after which the patients breathed O_2 spontaneously via a Magill's attachment for a further few minutes.

b) *Pentothal®-O_2-N_2O-d-Tubocurarine* (*C*). For at least 2 min initially the patients breathed 100 per cent O_2 in a partial circuit system with CO_2-absorption and an oxygen flow exceeding 10 liters per min. The composition of the gas delivered to the circuit system was then adjusted to 1 liter O_2 + 3 liters N_2O per minute, and 150 mg of Pentothal® was injected intravenously. After a short period of controlled ventilation the patients were intubated with a cuffed tube size 10 during neuromuscular block induced either with succinyl choline (50–75 mg) or d-Tubocurarine (20–40 mg). The ventilation was then taken over by a respirator[4]) connected to the anaesthesia apparatus.[1]) Muscular relaxation was maintained by means of d-Tubocurarine administered in total amounts of 52.0 $\pm$ 15.3 mg[5]) inclusive of any intubation dose. Ventilation was adjusted to give a tidal volume of 500 ml and a respiratory rate of 20 breaths/min. The expiration/inspiration time ratio was adjusted to 2:1. The ventilation was monitored regularly by means of a dry gas meter.[6])

After administration of 0.5–1.0 mg atropine, suction of the oral cavity, pharynx and trachea, and ventilation with 100 per cent O_2 the orotracheal tube was removed. The patient was then given neostigmine (4.02 $\pm$ 0.88 mg)[5]) and occasionally another 0.5 mg of atropine, and was ventilated via a face mask, pending a positive head lift test.

c) *Spinal nerve block* (*S*). The blocks were either subarachnoid (spinal anaesthesia) or extradural (continuous epidural anaesthesia via an indwelling catheter).

---

[1]) Anaesthesia apparatus: AGA Anestor Universal MDNK-23, AGA Ltd, Lidingö, Sweden.
[2]) Magill's tube (size 10).
[3]) Fluotec Vaporiser.
[4]) Spiropulsator MDNC —20, AGA Ltd, Lidingö, Sweden.
[5]) M $\pm$ SD.
[6]) Volumeter, Drägerwerk, Lübeck, Germany.

Spinal anaesthesia (*Ss*). After a subcutaneous injection of 50 mg of ephedrine and with the patient sitting up, the subarachnoid space was punctured distally to L III or L IV with an Antoni-Sise double needle. The local anaesthetic agents used were hyperbaric solutions of either tetracaine (1 per cent) or mepivacaine (4 per cent) in doses of 20 and 160 mg, respectively. Before the injection the location of the puncture needle in the subarachnoid space was confirmed by aspiration of cerebrospinal fluid. After the injection the patient were immediately placed supine in an approximately 10° head down position. The aim was anaesthesia below Th VI.

Owing to the insufficient duration of this kind of anaesthesia, the method was discarded in favour of

Continuous epidural anaesthesia via an indwelling catheter (*Se*). Local anaesthetic agents (lidocaine 2 per cent with epinephrine 1/160,000) were injected into the lumbar epidural space through a thin nylon catheter inserted by means of a Touhy needle, using the lateral approach. The tip of the catheter was introduced about 5 cm beyond the point of the needle in the epidural space. Peroperative anaesthesia, caudally to Th IV, was aimed at and was maintained with lidocaine—see above—in total doses of 606 ± 212 mg.[1]) Postoperative anaesthesia until completion of the postoperative examinations (ex.IV) was obtained with bupivacaine 0.5 per cent with epinephrine 1/200,000 in doses of 8–12 ml about every four hours in total doses of 242 ± 70.3 mg.[1]).

1.3.3. Postoperative management

Following the examinations made immediately after the operations (see 1.5) the patients were sent to the intensive care unit, where they were carefully supervised as regards circulation, ventilation, bleeding, fluid balance, drainage of the bladder etc. The author supervised all patients, particular care being given to cases of postoperative bleeding. As a matter of routine 5 liters of humidified O_2 per min was administered through a nasal catheter with its tip in the nasopharynx, until 30 minutes before the examinations on the morning of the day after the operation.

1.3.4. Fluid supply

Blood was administered during the operation as well as postoperatively in amounts corresponding to the blood loss measured or calculated. In addition, from patient 33 onwards, 500 ml of a 6 per cent dextran solution was given to compensate for the increased capacity of the circulation induced by the sympathetic block after the induction of anaesthesia. Only exceptionally were dextran solutions used to compensate for blood loss.

From patient 15 onwards, 100–300 ml of a 15 per cent mannitol solution was given peroperatively to enable the surgeon to visualize the ureteric orifices.

In addition, during the first 24 hours postoperatively, invertose solutions in amounts exceeding 1000 ml were administered.

To avoid fibrinolysis, epsilon-amino-caproic acid was given to each patient pre- or peroperatively in doses of at least 5 grams.

Table 3 illustrates the situation at examinations (ex.) III and IV, with regard to blood loss, blood and/or dextran substitution, replaced blood loss (see p. 22.) and fluid supply. Figure 2 shows replaced blood loss at ex. III and IV.

The patients left the intensive care unit on the morning of the first day postoperatively for further examinations (see 1.5), after which they were generally sent back to their respective wards.

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[1]) M ± SD.

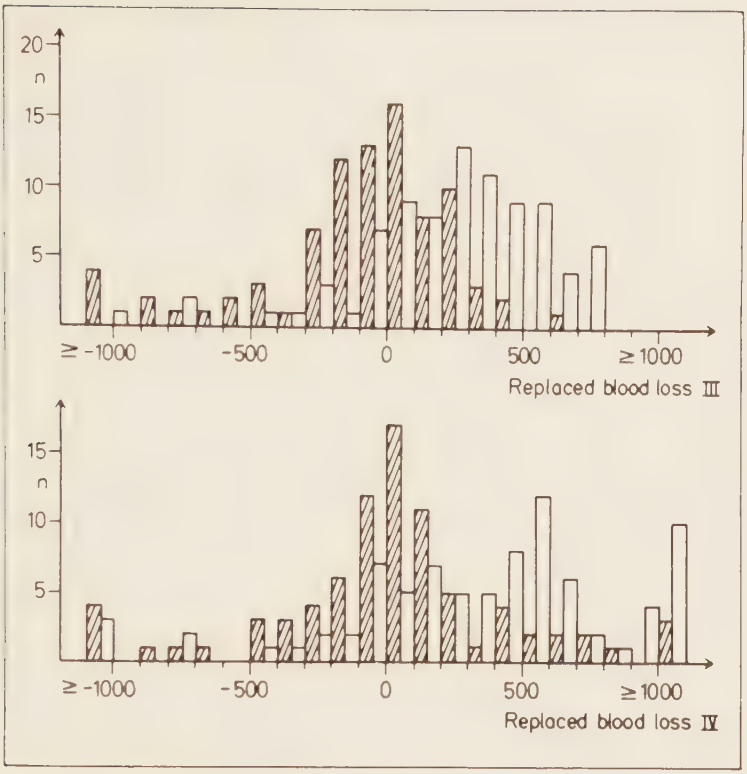

FIG. 2.—Frequency histograms for replaced blood loss (amount of blood and dextran given minus measured blood loss □, amount of blood given minus measured blood loss //// , in ml at postoperative ex. III and IV.

1.4 INVESTIGATION PROGRAMME

The basal oxygen uptake was determined shortly after admission of the patients to the hospital.

Two days before the operation an exercise test was performed on a bicycle ergometer.

All patients were fasted from midnight prior to the operation.

On the morning of the day of operation, the patients were taken in their beds to the laboratory of the anaesthesia department.

After a small incision made under local anaesthesia, the left radial artery was catheterized by direct puncture with a teflon catheter.[1]) In 55 patients, a polyethylene catheter (PE 160) was floated into the pulmonary artery from the exposed left basilic vein in the cubital fossa during continuous pressure recording. The tip of the catheter was considered to be in the main trunk of the pulmonary artery when the catheter had been inserted for

[1]) Infartkanyl, Ø 1.15 mm, Stille Ltd, Stockholm, Sweden.

an additional 10 cm after the pressure curve had changed from a typical right ventricular curve to a typical pulmonary artery curve.

The patients were examined in the supine position in their beds, as described in Table 4. Particular care was taken to ensure that as far as possible the different patients lay in the same position, and especially that individual patients were lying in the same position at the various examinations.

Preoperatively, the patients were also submitted to spirometry, while in the supine position, with determination of VC and $FEV_{1.0}$.

At each examination the room temperature, the rectal temperature of the patient and the barometer reading were recorded.

About 15 minutes and about 17 hours postoperatively the investigations described in Table 4 were repeated. The postoperative period is regarded here as commencing when the patients were definitely disconnected from the anaesthesia apparatus and/or had left the operation theatre.

In addition to this investigation programme, samples were taken from the radial artery in 79 patients at the end of the operation (ex.OP) for blood gas analysis. The samples were always collected during the same stage of the operation, viz. the suturing of the bladder.

In the text the various examinations are codified by the symbols given in "Symbols and notation" on page 5.

The investigation programme outlined above was not adhered to in the case of two patients. Inadvertently, patient no. 6 was premedicated before ex. II and was examined only by means of arterial blood samples at ex. II, OP, III and IV. Ex. OP and III could not be carried out on patient no. 29, since the operation was finished too late for the samples to be analysed.

Catheterization of the pulmonary artery was not introduced until the spring of 1966, so that mixed venous blood was only obtained from 55 patients.

Owing to various technical failures some samples were lost or gave evidently absurd values. The exclusion of these samples is not considered of significance for the results reported.

No peroperative or immediate postoperative mortality occurred. Patient no. 62, however, suffered a circulatory collapse immediately after the operation, with a non-measurable blood pressure, probably due to hypoventilation (halothane anaesthesia). Immediately before the collapse the Pa_{O_2} value was 32 mm Hg and Pa_{CO_2} 61 mm Hg. The circulation rapidly returned to normal and no clinical sequelae were observed subsequently.

1.5 METHODS

Oxygen uptake ($\dot{V}_{O_2}$, ml STPD/min) was determined at ex. I and V[1]) under standardized basal conditions. Duplicate determinations were made during consecutive 10-minute periods. The duplicate determinations allowed calculation of the error of the method for a single determination, which was found to be 4.3 ml O_2 STPD/min (= about 2.0 per cent).

Pulmonary ventilation ($\dot{V}_E$, l BTPS/min). The patients breathed atmospheric air. With the patients lying in a standardized supine position expired gas was collected during 10-minute periods. The patients, wearing nose-clips, breathed through a non-rebreathing

[1]) Spirograph IV, KIFA Ltd, Stockholm, Sweden.

valve[1]) with a rubber mouthpiece constructed to minimize leakage. The expired gas was conducted to a Douglas bag (150–200 liters) via a tube (30 mm inner diameter) and a three-way stopcock connected to either the Douglas bag or the ambient air.

Before starting the collection, the patients were given a few minutes to accustom themselves to the examination conditions. During this time, expired gas was collected in the tube system, and the Douglas bag was then emptied in a standardized way. Expired gas was collected for exactly ten minutes. The connection with the bag was always opened immediately after an expiration.

By means of a suction pump[2]) the bags were emptied with constant velocity via a dry gas meter[3]). The pump and the tube system were checked regularly for leakage. Through a side tube expired gas samples (about 3×70 ml) were transferred to mercury receptacles. The emptying of the bags was automatically stopped when a negative pressure of 2 mm Hg developed.

The volume thus measured was divided by the collecting time expressed in minutes and $\dot{V}_E$ is rendered in 1 BTPS/min. In all cases the body temperature was assumed to be 37.0°C.

Respiratory rate (f, number of breaths/min). During the collection of expired gas, the number of breaths was counted for not less than five minutes.

Tidal volume (V_T, ml BTPS). V_T was obtained by dividing $\dot{V}_E$ by f.

Qualitative analysis of expired gas. Expired gas was analysed, using Enghoff's modification of the Haldane apparatus (Enghoff, 1946)[40]. Double analyses were always made and fraction differences less than 0.04 volume per cent were accepted.

Oxygen uptake ($\dot{V}_{O_2}$, ml STPD/min) was calculated conventionally from the volume and composition of expired gas.

Respiratory exchange ratio (R). R was calculated as $\dot{V}_{CO_2}/\dot{V}_{O_2}$.

Physiological dead space (V_D, ml BTPS). Enghoff's modification (1938)[39] of the Bohr formula (1891)[20] was used to calculate V_D.

$$V_D = \frac{Pa_{CO_2} - P_{E\bar{C}O_2}}{Pa_{CO_2}} \times V_T;$$

Physiological dead space/tidal volume ratio (V_D/V_T, per cent). V_D/V_T was calculated from V_D and V_T determined as above.

Alveolar ventilation ($\dot{V}_A$, l BTPS/min). $\dot{V}_A$ was obtained according to the equation

$$\dot{V}_A = \dot{V}_E \times \left(1 - \frac{V_D/V_T}{100}\right);$$

Arterial oxygen tension (Pa_{O_2}, mm Hg). The samples were drawn up in all-glass syringes, the dead space of which had been filled with a heparin solution (5000 IU/ml). Before drawing the samples, the syringes were cooled to about +4 °C. The samples consisted of 8 ml and were collected in not less than 30 seconds. Nothing but heparin was added to the samples, which were immediately placed in iced water. The samples were analysed within the shortest possible period of time. Analyses were made by means of different, thermostated variants of the Clark electrode, according to Hilty & Meissl (1965)[64] on samples from patients 1–30, and according to Radiometer[4]), on samples from patients 31–86. The electrodes were calibrated against air and oxygen mixtures analysed according

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[1]) Polyvalve Simplex, AGA Ltd, Lidingö, Sweden [72].

[2]) Limmatquai 3, Fricar AG, Zürich, Switzerland.

[3]) D 10–U2½, Nordgas Ltd, Stockholm, Sweden.

[4]) E 5046, Radiometer AS, Copenhagen, Denmark, modified at the laboratory [63].

to ENGHOFF (1946)[40]. The peak value was read off within 90 seconds of the introduction of the sample into the electrode. The blood-gas factor was determined for each electrode. Corrections for temperature deviations were made according to Bradley et al. (1956)[23], the rectal temperature at ex. OP being assumed to be equal to that at ex. III.

The error of the method for a single determination calculated from double determinations made with the Radiometer electrode was 1.0 mm Hg at Pa_{O_2} less than 200 mm Hg and 3.1 mm Hg at Pa_{O_2} exceeding 200 mm Hg.

Mixed venous oxygen tension ($P\bar{v}_{O_2}$, mm Hg). $P\bar{v}_{O_2}$ was calculated from $S\bar{v}_{O_2}$ according to SEVERINGHAUS (1958)[112], with allowance for rectal temperature and pH_a, $pH\bar{v}$ having been assumed to vary as pH_a.

Arterial pH (pH_a, pH-units). A thermostated glass electrode combined with a calomel electrode was used for these measurements[1]). The pH-meter was calibrated against buffer solutions standardized according to the norms of the National Bureau of Standards (USA). Corrections for temperature differences were made according to ROSENTHAL (1948)[107] and for Pa_{O_2}-values below 105 mm Hg according to BERGLUND et al. (1964)[16].

Arterial carbon dioxide tension (Pa_{CO_2}, mm Hg). In samples from patients 1–15, Pa_{CO_2} was determined by means of the SEVERINGHAUS-BRADLEY (1958)[113] modification of Stow's electrode. The electrode was calibrated against test gases analysed according to ENGHOFF (1946)[40]. The values obtained were corrected for deviations of temperature according to BRADLEY et al. (1956)[23].

In the samples from patients 16–86, Pa_{CO_2} was determined according to SIGGAARD-ANDERSEN (1962)[116]; pH in whole blood was determined after equilibration with different known CO_2-O_2 mixtures. Double determinations of pH in equilibrated blood were always made. The error of a single determination was 0.006 pH-units. The equilibration gases used contained about 4 and 8 per cent CO_2 in O_2, the exact fractions at the separate analyses were determined according to ENGHOFF (1946)[40]. Pa_{CO_2} was obtained from nomograms by means of equilibration lines and pH_a determined and corrected as above.

Standard bicarbonate (HCO_3^-, mEq/l) and *base excess* (B.E., mEq/l). The equilibration lines obtained as above also served as the basis for determination of HCO_3^- and B.E. according to SIGGAARD-ANDERSEN (1962)[116].

Alveolar oxygen tension (PA_{O_2}, mm Hg). PA_{O_2} was calculated according to ASMUSSEN & NIELSEN (1960)[8]. According to NUNN (1963)[95] the corresponding formula is also valid for non-steady-state conditions.

$$PA_{O_2} = PI_{O_2} - Pa_{CO_2}\frac{FI_{O_2} - FE_{O_2}}{FE_{CO_2}};$$

Alveolo-arterial oxygen tension gradient ($A\text{-}aD_{O_2}$, mm Hg). $A\text{-}aD_{O_2}$ was obtained by subtraction:

$$A\text{-}aD_{O_2} = PA_{O_2} - Pa_{O_2};$$

Oxygen saturation (S_{O_2}, per cent). S_{O_2} was determined spectrophotometrically by a Beckman B spectrophotometer. 10-ml samples were taken in cooled, all-glass syringes, whose known dead space was filled with a heparin solution (5000 IU/ml). The syringes containing the samples were kept in iced water, and before the analyses the samples were mixed with a drop of mercury, after which 0.8 ml of blood were hemolysed with saponin[2]). The extinction at 475 nm was read off. The isosbestic point was at about 505 nm. An NaC-11 »N« cuvette[3]), whose lucite had been exchanged for OS-glass (Karendal et al. 1968)[73] was used for the analyses. The cuvette factor was determined before each analysis.

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[1]) PMH 27, Radiometer AS, Copenhagen, Denmark.

[2]) 10 g per 25 ml M/15 Na_2HPO_4.

[3]) The Waters Corporation, Rochester, Minnesota, USA.

Samples from each examination were calibrated with reduced and saturated samples. The error of a single determination was 0.002 units, which corresponds to 0.20 per cent saturation.

Haemoglobin concentration (Hb, g/100 ml). Hb was determined spectrophotometrically after conversion of haemoglobin to cyanmethaemoglobin with »Aculute«[1]). Triple determinations were made. The error of a single determination was 0.0061 extinction units, which corresponds to 0.02 g Hb/100 ml.

Haematocrit (hct, per cent). Hct was determined in micro capillary tubes after centrifugation for 5 min at 10000 rpm. Corrections for trapped plasma were not made (Garby & Vuille, 1961)[46].

Oxygen content in blood (C_{O_2}, ml/100 ml). C_{O_2} is expressed as the amount of haemoglobin-bound and physically dissolved oxygen in whole blood at 37.0 °C. One gram of haemoglobin was considered to bind 1.34 ml O_2[2]) and 100 ml of whole blood to dissolve 0.003 ml O_2 per mm Hg. S_{O_2} and Hb were determined as above.

Cardiac output ($\dot{Q}$, l/min). $\dot{Q}$ was determined according to Fick (1870)[43]:

$$\dot{Q} = \frac{\dot{V}_{O_2}}{AVD_{O_2}};$$

Average ventilation-perfusion ratio ($\dot{V}_A/\dot{Q}$). $\dot{V}_A/\dot{Q}$ was obtained after dividing $\dot{V}_A$ by $\dot{Q}$—both obtained as above.

Available oxygen ($\dot{C}a_{O_2}$, ml/min), is given as the product of Ca_{O_2} and $\dot{Q}$.

Oxygen utilization coefficient (O_2 uc, per cent). O_2 uc is given as:

$$O_2 \text{ uc} = \frac{\dot{V}_{O_2}}{\dot{C}a_{O_2}} \times 100;$$

Thus the extraction of oxygen from arterial blood by the tissues was considered equal to the oxygen uptake in the lungs.

Shunt blood flow/cardiac output ratio ($\dot{Q}s/\dot{Q}t$, per cent). $\dot{Q}s/\dot{Q}t$ was calculated according to Sackur (1897)[108] and Berggren (1942)[14]:

$$\dot{Q}s/\dot{Q}t = \frac{Cc_{O_2} - Ca_{O_2}}{Cc_{O_2} - C\bar{v}_{O_2}};$$

where Cc_{O_2} is the oxygen content in end-capillary pulmonary blood. Ca_{O_2} and $C\bar{v}_{O_2}$ were obtained as above. Cc_{O_2} was calculated as the sum of haemoglobin-bound and physically dissolved oxygen in the end-capillary pulmonary blood. Pc_{O_2} was regarded as equal to $P\bar{A}_{O_2}$ and the haemoglobin assumed to be fully saturated at P_{O_2} exceeding 200 mm Hg. At $P\bar{A}_{O_2}$ below 200 mm Hg (case 77), Sc_{O_2} was calculated from Pc_{O_2} according to Severinghaus (1958)[112]. The investigations were always made at $P\bar{A}_{O_2}$ exceeding 600 mm Hg. $P\bar{A}_{O_2}$ was determined as Pb — 47 — Pa_{CO_2} — $F\bar{A}_{N_2}$ (Pb — 47) mm Hg. $F\bar{A}_{N_2}$ was determined during oxygen breathing by means of an N_2-meter according to Lundin & Åkesson (1954)[83]. The duration of the oxygen breathing was always less than 10 minutes.

Peak expiratory flow (PEF, l/min). PEF was determined with the patients supine, using

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[1]) Ortho Pharmaceutical Corporation, New Jersey, USA.

[2]) Recently, our laboratory has used the value 1.39 ml O_2/g Hb for the oxygen binding capacity of haemoglobin (cf. Perutz et al., 1960)[100] on the recommendation of the Technical Committee of The Swedish Society of Clinical Physiology (Garby et al. 1968)[45]. However, for the results presented in this paper, the value of 1.34 was used throughout.

for all patients the same Peak Flow Meter[1]), the precision of which has been stated by the manufacturer to be ± 10 per cent. The highest value read off at no fewer than three correctly made tests is reported.

Rectal temperature (t_{rect}, °C). t_{rect} was measured with a mercury thermometer. The same thermometer was used on the different measuring occasions of the same patient. On each measuring occasion the thermometer was inserted to the same depth in the rectum. (cf. Mead & Bonmarito, 1949)[87].

Blood loss in irrigating fluids and in cloths and compresses was determined spectrophotometrically[2]). Blood loss was measured both during the operation and from its completion to ex. IV.

Replaced blood loss (ml) is reported as the amount of blood and/or dextran given *minus* the measured blood loss and the approximate amount of blood taken for analyses.

In order to classify the preoperative circulatory and ventilatory status of the patients, they also underwent an exercise test and spirometry.

The exercise test was performed on an electrically braked bicycle ergometer[3]). For further details see part II.

Spirometry was carried out by means of a spirometer type KIFA B[4]), which is a modification (Berglund et al. 1963)[15] of that described by Bernstein et al. (1952)[17]. The patients lay in the supine position and the investigation procedure was essentially the same as described by Birath et al. (1963)[18], Berglund et al. (1963)[15] and Grimby & Söderholm (1963)[55]. The values obtained are expressed in per cent of the predicted values [15, 18, 55] for patients sitting up.

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[1]) Wright's Peak Flow Meter, Airmed Ltd, Harlow, England.
[2]) Perdometer, Linson Ltd, Stockholm, Sweden.
[3]) Elema-Schönander Ltd, Stockholm, Sweden.
[4]) Instrumenta Ltd, Lund, Sweden.

Chapter 2

RESULTS

2.1 GENERAL RESULTS

The postoperative changes are reported in this section while the peroperative changes are reported in section 2.5. The results are given in Tables 5–32 (pp. 99–108). The mean changes are also indicated by columns in Figs. 4–29, (pp. 29–39).

The results are given under the headings

A. Oxygen uptake,

B. Oxygenation of blood:
   1. Ventilation,
   2. Alveolo-arterial oxygen transport,

C. Oxygen transport in blood, and

D. Acid-base balance in arterial blood.

A. *Oxygen uptake*

The oxygen uptake (Table 5, Fig. 4) showed a significant increase at ex. II. At ex. III $\dot{V}_{O_2}$ had increased by 42 per cent compared with the initial level at ex. I, a highly significant increase. At ex. IV there was still a highly significant increase of $\dot{V}_{O_2}$, i.e. + 22 per cent. Before the patients were discharged from hospital, however, $\dot{V}_{O_2}$ had returned to the initial level.

The rectal temperatures at ex. II–IV are given in Table 6 and Fig. 5. The changes are highly significant and consist of a reduction by 1.0 °C at ex. III and an increase by 0.8 °C at ex. IV, in relation to the temperature at ex. II, when no value exceeded 37.5 °C.

B. *Oxygenation of blood*

1. Ventilation

The arterial carbon dioxide tension (Table 7, Fig. 6) showed very little change. Some carbon dioxide retention was noted at ex. III, but this was only of probable significance. At ex. IV the mean Pa_{CO_2} was slightly lower than preoperatively.

The pulmonary ventilation (Table 8, Fig. 7) was increased by 37 and 30 per cent at ex. III and IV, respectively.

The alveolar ventilation (Table 9, Fig. 8) was increased more than the pulmonary ventilation at ex. III (43 per cent). The increase of $\dot{V}_A$ at ex. IV was less than that of $\dot{V}_E$ (26 per cent), however.

The tidal volume (Table 10, Fig. 9) was significantly increased only at ex. III (17 per cent).

The respiratory rate (Table 11, Fig. 10) was highly significantly changed. Compared with the preoperative condition it was increased by 20 per cent at ex. III and by 31 per cent at ex. IV.

The respiratory exchange ratio (Table 12, Fig. 11) was also increased significantly at the two postoperative examinations, the increases amounting to 7 per cent and 5 per cent, respectively.

The peak expiratory flow (Table 13, Fig. 12) was decreased by 39 per cent and 30 per cent at ex. III and IV, respectively. It should be pointed out, however,that several patients were unable to cooperate at ex. III and have consequently not been included in the results. The values reported for ex. III are thus considered to be falsely high.

2. Alveolo-arterial oxygen transport

The arterial oxygen tension during air breathing (Table 14, Fig. 13) was 10 per cent and 5 per cent lower at ex. III and IV, respectively, than preoperatively. The statistical significance of these changes is shown in the table.

The alveolo-arterial oxygen tension gradient (Table 15, Fig. 14) was highly significantly increased both at ex. III and IV. This increase amounted to 9 mm Hg at ex. III and 7 mm Hg at ex. IV.

The physiological dead space (Table 16. Fig 15) was changed very little at ex. III, whereas at ex. IV it was highly significantly greater (10 per cent) than at ex. II.

The physiological dead space/tidal volume ratio (Table 17, Fig. 16) was significantly changed only at ex. IV when it was increased by 10 per cent.

The shunt blood flow/cardiac output ratio (Table 18, Fig. 17) was increased by 55 per cent at ex. III and by 42 per cent at ex. IV.

The average ventilation—perfusion ratio (Table 19, Fig. 18) was also increased at the postoperative examinations, by 27 per cent and 15 per cent, respectively.

C. *Oxygen transport in blood*

The haemoglobin concentration (Table 20) measured in arterial blood was lower by 6 per cent at ex. III and by 4 per cent at ex. IV than preoperatively.

The haematocrit values (Table 21) showed essentially similar changes.

The arterial oxygen saturation (Table 22, Fig. 19) was 2.3 per cent lower at ex. III and 1.7 per cent lower at ex. IV than preoperatively. The statistical significance of the changes is shown in the table.

The mixed venous oxygen saturation (Table 23, Fig. 20) was changed at both postoperative examinations. The 10 per cent decrease at ex. III is highly significant, whereas the 4 per cent decrease at ex. IV is only of probable significance.

The oxygen content of arterial blood (Table 24, Fig. 21) was lower than preoperatively at both ex. III and IV, the decreases amounting to 10 per cent and 6 per cent, respectively.

The oxygen content of mixed venous blood (Table 25, Fig. 22) also decreased highly significantly. The absolute decrease in mixed venous blood was greater, however, than that in arterial blood –20 per cent and 9 per cent, respectively.

The arterio-venous oxygen difference (Table 26, Fig. 23) was increased by 12 per cent at ex. III, and this change was probably significant.

The cardiac output (Table 27, Fig. 24) was increased at both postoperative examinations, the increase at ex. III being 30 per cent and that at ex. IV 17 per cent.

The available oxygen (Table 28, Fig. 25) increased by 15 per cent and 9 per cent at ex. III and ex. IV, respectively. The former increase is significant, whereas the latter is of only probable significance.

The oxygen utilization coefficient (Table 29, Fig. 26 showed a highly significant increase of 29 per cent at ex. III. The 9 per cent increase at ex. IV is probably significant.

D. *Acid-base balance in arterial blood*

The arterial pH (Table 30, Fig. 27) was decreased by 0.50 per cent at ex. III and by 0.16 per cent at ex. IV. The former decrease is highly significant, whereas the latter is probably significant.

The standard bicarbonate (Table 31, Fig, 28) was highly significantly decreased (by 6 per cent) at ex. III. The 3 per cent decrease at ex. IV is probably significant.

The arterial base excess (Table 32, Fig. 29) at ex. III and IV was decreased compared with the preoperative values. These decreases amounted to 2.1 mEq/l and 1.5 mEq/l, respectively.

2.2 RESULTS RELATED TO AGE

In order to estimate the importance of age factors in the postoperative changes in some parameters investigated, two groups of 21 patients each were chosen from the series:

B_{age} — the patients who were younger than 69 years and 6 months at the time of the operation, and

A_{age} = the patients who were older than 77 years and 6 months at the time of the operation.

The distribution of the patients into the different anaesthetic groups is shown in Table 33. The oldest patients are not underrepresented in anaesthetic group H.

The results are summarized in Tables 34–36.

A. *Oxygen uptake*

The oxygen uptake showed the greatest increase in group A_{age} at both ex. III and ex. IV. The differences are not significant, however.

The rectal temperature was decreased more in group A_{age} than in group B_{age} at ex. III, and was increased more in group B_{age} than in group A_{age} at ex. IV.

B. *Oxygenation of blood*

1. Ventilation

The arterial carbon dioxide tension was reduced in group A_{age} and elevated in group B_{age} at ex. III.

The pulmonary ventilation was increased most in group A_{age} at both postoperative examinations.

2. Alveolo-arterial oxygen transport

The arterial oxygen tension decreased in a similar way in the two groups.

The physiological dead space showed similar changes in the two groups.

The physiological dead space/tidal volume ratio was changed postoperatively to essentially the same extent in both groups.

The shunt blood flow/cardiac output ratio was increased postoperatively in both groups. No significant differences between the changes in the two groups were found at either of the examinations.

C. *Oxygen transport in blood*

The arterio-venous oxygen difference showed a greater increase in group A_{age} than in group B_{age} both at ex. III and ex. IV.

The cardiac output was also increased more in group A_{age} than in group B_{age} at both postoperative examinations.

The available oxygen increased to a greater extent, though not significantly, in group A_{age} than in group B_{age}.

The oxygen utilization coefficient was increased similarly in both groups at the postoperative examinations.

D. *Acid-base balance in arterial blood*

The arterial base excess showed a greater decrease in group A_{age} than in group B_{age} at ex. III, the difference being probably significant.

2.3 RESULTS RELATED TO PREOPERATIVE VENTILATORY FUNCTION

For this evaluation two groups of 30 patients each were chosen from the series:

A_{vent} = Patients who at preoperative spirometry showed the best VC and $FEV_{1.0}$ values in relation to their age and height, and

B_{vent} = Patients who at preoperative spirometry showed the poorest VC and $FEV_{1.0}$ values in relation to their age and height.

The normal comparative series used for this classification were those reported by Berglund et al. (1963)[15], Birath et al. (1963)[18] and Grimby & Söderholm (1963)[55]. The mean age of the patients in the present study and their VC and $FEV_{1.0}$ expressed as a percent-

age of individually predicted values can be seen in Table 37. The distribution of the patients into anaesthetic groups is shown in Table 38.

The results are presented in Table 39.

B. *Oxygenation of blood*

1. Ventilation

The arterial carbon dioxide tension was changed in a similar way in both groups.

The pulmonary ventilation showed a greater increase in group A_{vent} than in group B_{vent} at ex. III. The difference is not significant, however.

The tidal volume was changed in a similar way in both groups.

The peak expiratory flow was percentually most decreased in group A_{vent}. The differences between the changes in the two groups were not significant at ex. III and probably significant at ex. IV.

2. Alveolo-arterial oxygen transport.

The arterial oxygen tension decreased to essentially the same extent in both groups.

The alveolo-arterial oxygen tension gradient increased similarly in both groups.

The physiological dead space increased in both groups.

The physiological dead space/tidal volume ratio was decreased in group A_{vent} at ex. III in contrast to in group B_{vent}, where there was an increase. The difference between these changes is probably significant.

The shunt blood flow/cardiac output ratio increased most in group B_{vent} but the difference between the two groups in this respect is not significant.

2.4 RESULTS RELATED TO PREOPERATIVE PHYSICAL WORKING CAPACITY

To evaluate the importance of the preoperative circulatory status in the postoperative changes of some investigated parameters, the patients having the best physical working capacity (A_W) were compared with those in whom this was poorest (B_W).

As a selective parameter, W_{lact} was used. Patients showing $W_{lact} \geq 500$ kpm/min were ranged under group A_W, and those with $W_{lact} \leq 400$ kpm/min under group B_W.

Table 40 shows the mean age, number of patients and their distribution in groups according to form of anaesthesia within the two groups.

As is evident from Table 41, there were no significant differences between the two groups with regard to the parameters investigated.

2.5 RESULTS RELATED TO TYPE OF ANAESTHESIA

The patients were divided into three groups, H, C and S, according to the type of anaesthesia used. (See p. 15–16). The division was made at random, and as Table 42 shows, the groups of patients did not differ as regards age, height, weight or BSA. The subgroups Ss (spinal anaesthesia) and Se (epidural anaesthesia) are treated jointly under the heading S for ex. OP and ex. III, whereas for ex. IV they are treated separately. It is considered that the

effect of these methods of anaesthesia was essentially equivalent at ex. III, while at ex. IV the patients in group Se were still anaesthetized, in contrast to those of group Ss.

Owing to the gradually diminishing effect of the spinal anaesthesia in patients 19 and 39, the anaesthesia was replenished at the end of the operation with O_2-N_2O-halothane via a face mask. The patients were fully conscious at ex. III and were then included in group S. Owing to an incomplete effect of the spinal anaesthesia in patient 15, O_2-N_2O-halothane was administered throughout the operation. This patient is excluded. In patient 75 a dural lesion was caused by an attempt to insert an epidural catheter, resulting in spinal anaesthesia up to the level of Th II after the injection of 3 ml of a local anaesthetic. The catheter was removed and the patient was included under group Ss.

The results of these investigations are reported only in the form of figures, where in addition to the changes of the different parameters in the anaesthetic groups, the mean changes in the whole series are shown in columns. The statistical significances of the differences between the changes in the various groups at the various examinations are summarized in Tables 43–46.

Blood loss

The peroperative as well as the postoperative bleeding varied within very wide limits. The average blood losses in the different anaesthetic groups are reported in Table 47, while Figure 3 shows the wide variation.

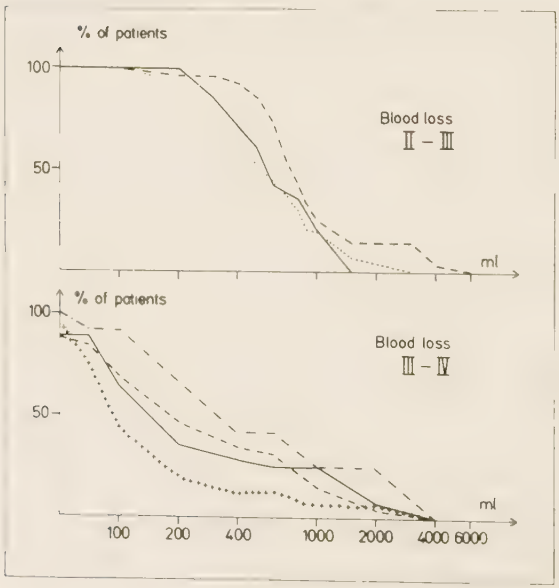


Fig. 3.—Peroperative (between ex. II and ex. III) and postoperative (between ex. III and ex. IV) blood loss in ml in the different anaesthetic groups (H:———, C: – – –, S: ....., Ss: –·–·–, Se: +++). Given on the ordinate is the percentage number of patients in the different anaesthetic groups who during the time period mentioned above lost more blood than the amounts given on the abscissa.

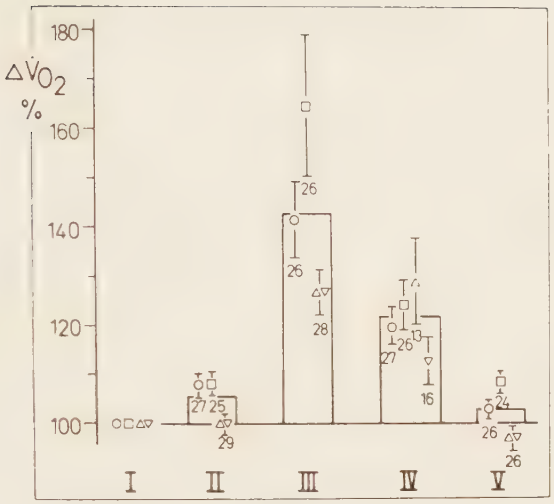


FIG. 4.—Relative values (M ± SEM) for oxygen uptake at immediately preoperative ex. II, and at postoperative ex. III, IV and V in the anaesthetic groups (O = group H, □ = group C, △ ▽ = group S, △ = group Ss, ▽ = group Se). Number of patients in each group is indicated under the symbols. The columns indicate the mean changes in the total series.

A. *Oxygen uptake*

The oxygen uptake (Fig. 4) was most increased in group C at ex. III. This increase is probably significantly greater than that in group S. At ex. II as well as at ex. V there was a decrease of $\dot{V}_{O_2}$ in group S.

The rectal temperature (Fig. 5) showed similar changes in the various groups.

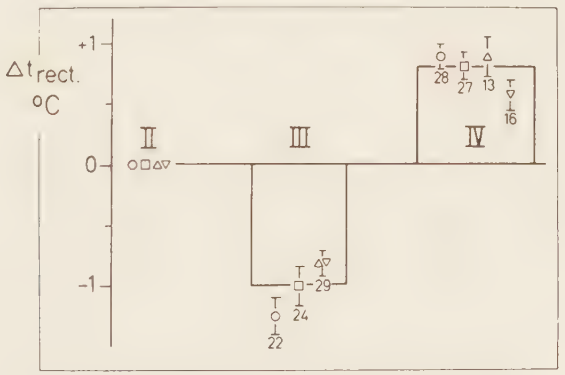


Fig. 5.—Relative values (M ± SEM) for rectal temperature at postoperative ex. III and IV in the anaesthetic groups. Symbols as in Fig. 4.

B. *Oxygenation of blood*

1. Ventilation

The arterial carbon dioxide tension (Fig. 6) changed differently in the various groups. The significance of the differences is shown in Table 43. At ex. OP,

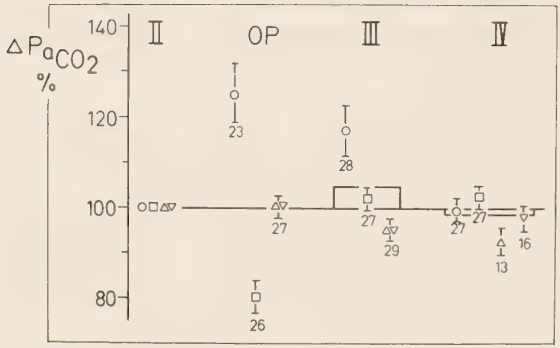


Fig. 6.—Relative values (M ± SEM) for arterial carbon dioxide tension at peroperative ex. OP, and postoperative ex. III and IV in the anaesthetic groups. Symbols as in Fig. 4.

different ventilation conditions in the groups were produced by the different types of anaesthesia applied. At ex. III, Pa_{CO_2} was significantly increased in group H, unchanged in group C and probably significantly lowered in group S —all in comparison with the preoperative level.

The pulmonary ventilation (Fig. 7) was increased in a similar way in all the groups at ex. III. At ex. IV the increase in group Ss was probably greater than that in group H.

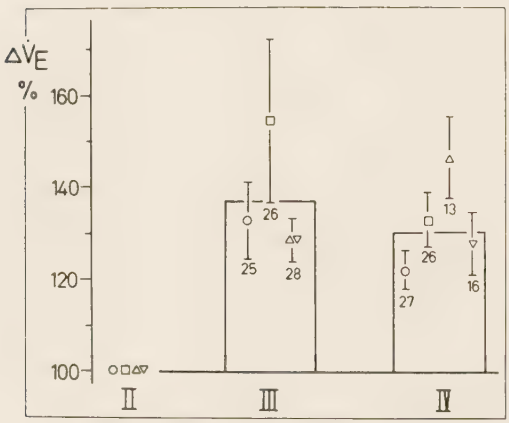


Fig. 7.—Relative values (M± SEM) for pulmonary ventilation at postoperative ex. III and IV in the anaesthetic groups. Symbols as in Fig. 4.

The alveolar ventilation (Fig. 8) increased analogously in all groups.

The tidal volume (Fig. 9) at ex. III was increased to a smaller extent in group H than in the two other groups.

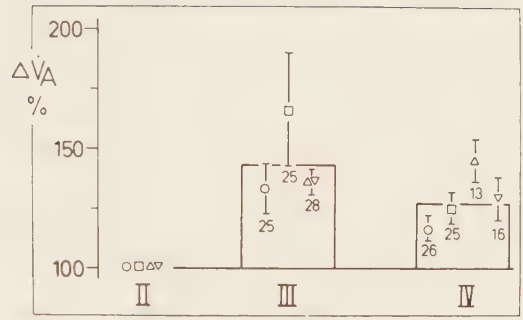


FIG. 8.—Relative values (M ± SEM) for alveolar ventilation at postoperative ex. III and IV in the anaesthetic groups. Symbols as in Fig. 4.

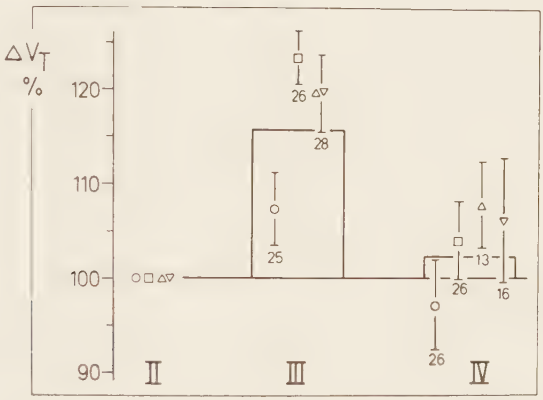


FIG. 9.—Relative values (M ± SEM) for tidal volume at postoperative ex. III and IV in the anaesthetic groups. Symbols as in Fig. 4.

The respiratory rate (Fig. 10) showed a probably significantly higher increase in group H than in group S at ex. III.

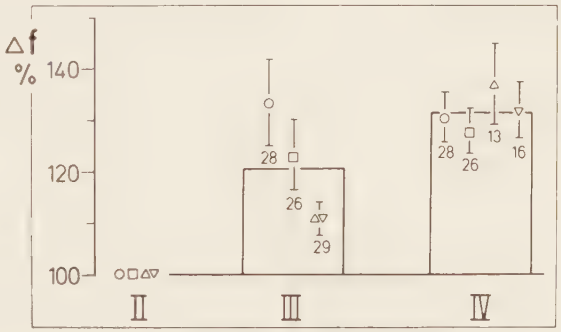


FIG. 10.—Relative values (M ± SEM) for respiratory rate at postoperative ex. III and IV in the anaesthetic groups. Symbols as in Fig. 4.

The respiratory exchange ratio (Fig. 11) changed in an essentially similar way in all groups.

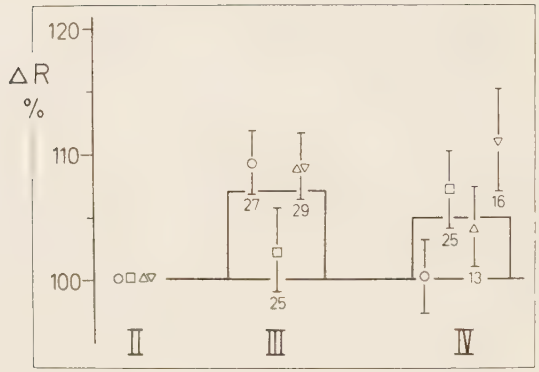


Fig. 11.—Relative values (M ±SEM) for respiratory exchange ratio at postoperative ex. III and IV in the anaesthetic groups. Symbols as in Fig. 4.

The peak expiratory flow (Fig. 12) was decreased to a smaller extent in group S than in group H and C at ex. III; these differences were highly significant. At ex. IV, the group with a residual anaesthetic effect (Se) also showed smaller changes than groups H and C, but there was no difference in comparison with group Ss.

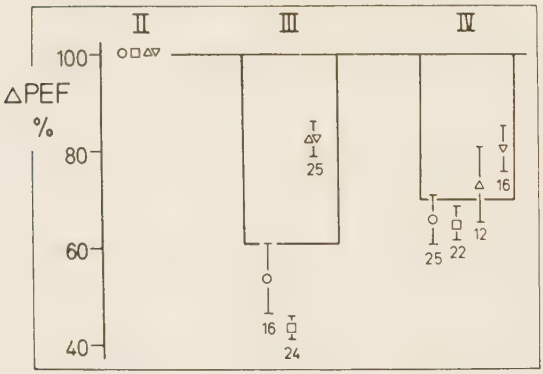


Fig. 12.—Relative values (M±SEM) for peak expiratory flow at postoperative ex. III and IV in the anaesthetic groups. Symbols as in Fig. 4.

2. Alveolo-arterial oxygen transport

The arterial oxygen tension (Fig. 13) changed differently in the various groups. The oxygen concentration in the inhaled gases during anaesthesia varied, however, in the different anaesthetic groups. At ex. III a slight increase of Pa_{O_2} was noted in group S—a change which differed from those in groups H and C. Also at ex. IV the changes in group Ss differed from those in groups H and C.

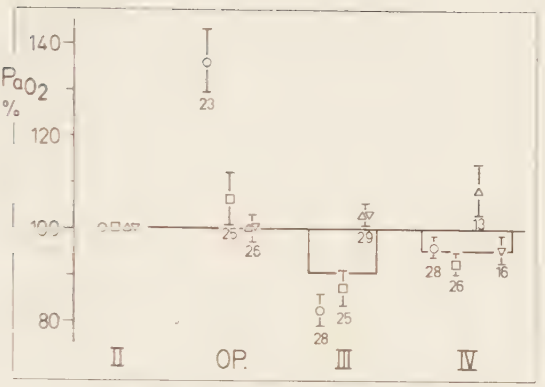


FIG. 13.—Relative values (M ± SEM) for arterial oxygen tension at peroperative ex. OP and postoperative ex. III and IV in the anaesthetic groups. Symbols as in Fig. 4.

The alveolo-arterial oxygen tension gradient (Fig. 14) at ex. III showed a probably greater increase in groups H and C than in group S. At ex. IV groups C and Ss probably differed significantly.

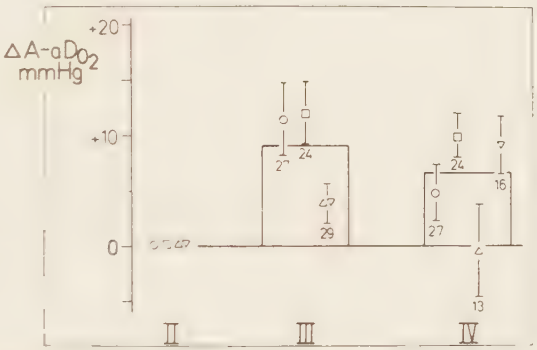


FIG. 14.—Relative values (M±SEM) for alveolo-arterial oxygen tension gradient at postoperative ex. III and IV in the anaesthetic groups. Symbols as in Fig. 4.

The physiological dead space (Fig. 15) was increased in an essentially similar manner in all groups both at ex. III and IV.

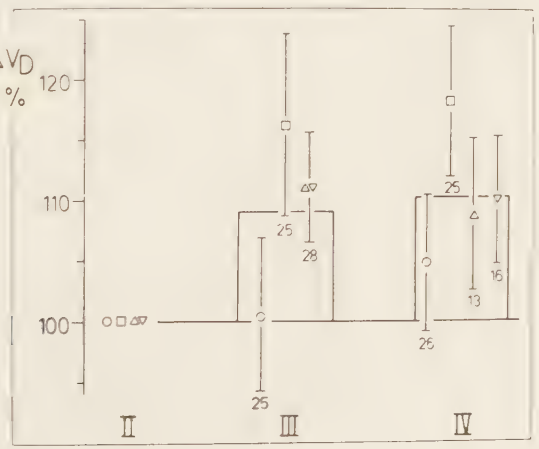


FIG. 15.—Relative values (M ± SEM) for physiological dead space at postoperative ex. III and IV in the anaesthetic groups. Symbols as in Fig. 4.

The physiological dead space/tidal volume ratio (Fig. 16) showed similar changes in the different groups at ex. III. At ex. IV, however, the ratio was probably increased to a greater extent in groups H and C than in group Ss.

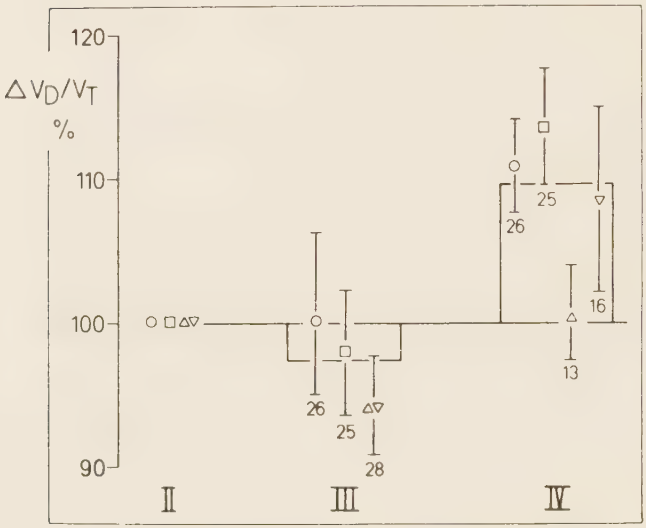


Fig. 16.—Relative values (M ± SEM) for physiological dead space/tidal volume ratio at postoperative ex. III and IV in the anaesthetic groups. Symbols as in Fig. 4.

The shunt blood flow/cardiac output ratio (Fig. 17) was increased within a wide range at ex. III, to a greater extent in group H than in group S.

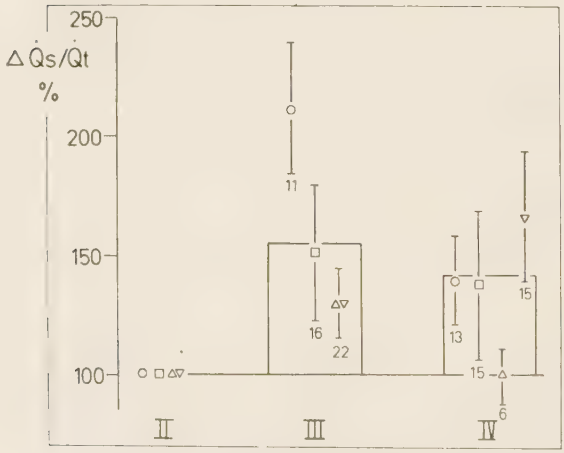


Fig. 17.—Relative values (M ±SEM) for shunt blood flow/cardiac output ratio at postoperative ex. III and IV in the anaesthetic groups. Symbols as in Fig. 4.

The average ventilation–perfusion ratio (Fig. 18) was probably more increased in group C than in groups H and S at ex. III.

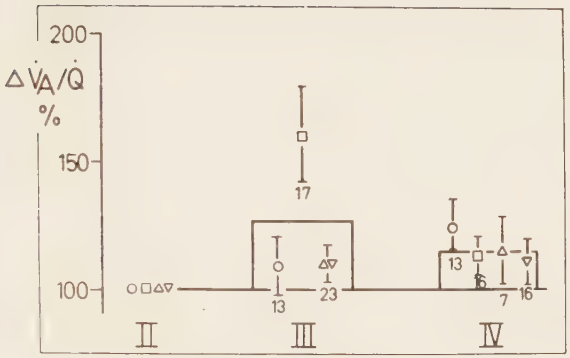
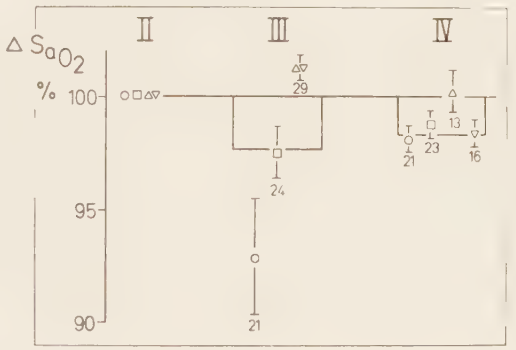


Fig. 18.—Relative values (M ± SEM) for average ventilation—perfusion ratio at postoperative ex. III and IV in the anaesthetic groups. Symbols as in Fig. 4.

C. *Oxygen transport in blood*

The arterial oxygen saturation (Fig. 19) was decreased in groups H and C but not in group S at ex. III. These changes are significantly different.



(Fig. 19.—Relative values (M±SEM) for arterial oxygen saturation at postoperative ex. III and IV in the anaesthetic groups. Symbols as in Fig. 4.

The mixed venous oxygen saturation (Fig. 20) showed a non-significant increase at ex. III in group S and a marked decrease in group H and also especially group C. The statistical significances of these differences are shown in Table 45.

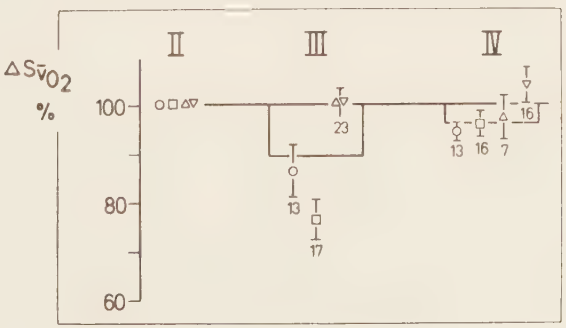


Fig. 20.—Relative values (M ±SEM) for mixed venous oxygen saturation at postoperative ex. III and IV in the anaesthetic groups. Symbols as in Fig. 4.

The oxygen content of arterial blood (Fig. 21) was decreased to an essentially similar extent in the different groups at the postoperative examinations, however.

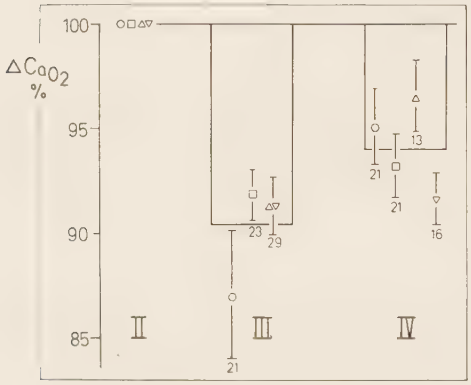


Fig. 21.–Relative values (M±SEM) for oxygen content of arterial blood at postoperative ex. III and IV in the anaesthetic groups. Symbols as in Fig 4.

The oxygen content of mixed venous blood (Fig. 22) was decreased more in group C than in group S at ex. III—a highly significant difference.

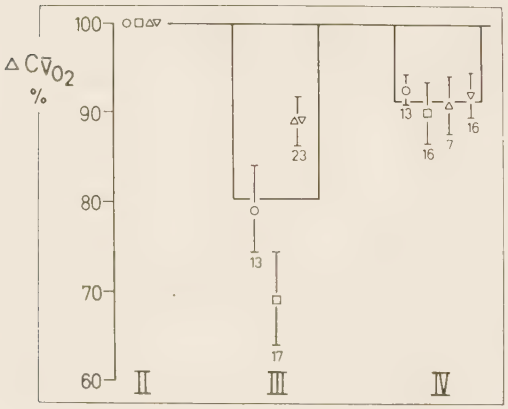


Fig. 22.—Relative values (M± SEM) for mixed venous oxygen content at postoperative ex. III and IV in the anaesthetic groups. Symbols as in Fig. 4.

The arterio-venous oxygen difference (Fig. 23) at ex. III was markedly increased in group C, in contrast to the slight, and non-significant, decrease in groups H and S. The differences between groups C and H and between groups C and S are highly significant.

The cardiac output (Fig. 24) was changed in a similar way in the different groups at ex. III. At ex. IV, the increase of this value in group Se was probably greater than that in group H.

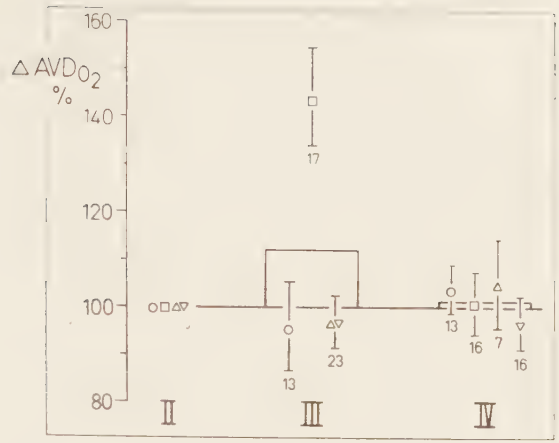


FIG. 23.—Relative values (M ± SEM) for arteriovenous oxygen difference at postoperative ex. III and IV in the anaesthetic groups. Symbols as in Fig. 4.

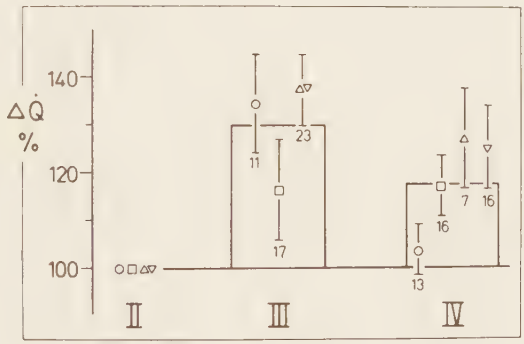


FIG. 24.—Relative values (M ± SEM) for cardiac output at postoperative ex. III and IV in the anaesthetic groups. Symbols as in Fig. 4.

The available oxygen (Fig. 25) was increased in the same way as the cardiac output in the different groups at ex. III. The changes in groups Se and H were probably significantly different at ex. IV.

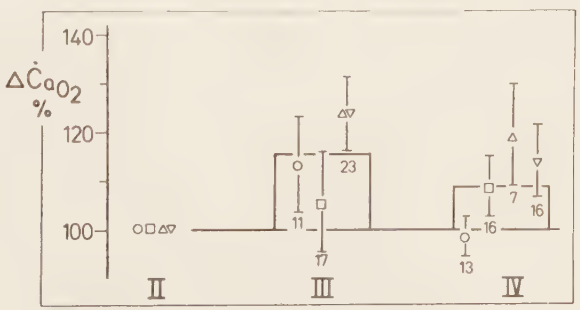


FIG. 25.—Relative values (M±SEM) for available oxygen at postoperative ex. III and IV in the anaesthetic groups. Symbols as in Fig. 4.

The oxygen utilization coefficient (Fig. 26) at ex. III was increased most in group C, which group thereby differs from group H and specially from group S.

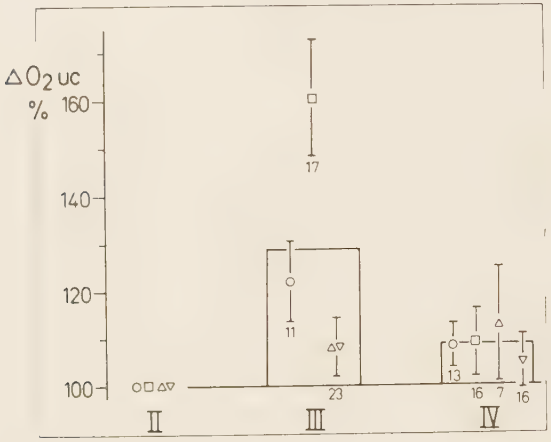


Fig. 26.—Relative values (M ±SEM) for oxygen utilization coefficient at postoperative ex. III and IV in the anaesthetic groups. Symbols as in Fig. 4.

D. *Acid-base balance in arterial blood*

The arterial pH (Fig. 27) at ex. OP was reduced to a highly significantly greater extent in group H than in group S. The increase of pH_a in the hyperventilated C-group contrasted to the decrease in the spontaneously breathing H and S groups. At ex. III pH_a was lower than preoperatively in all the groups, especially in group H.

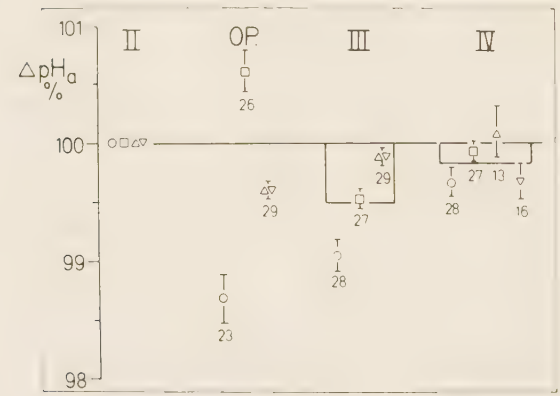


Fig. 27.—Relative values (M ±SEM) for arterial pH at peroperative ex. OP, and postoperative ex. III and IV in the anaesthetic groups. Symbols as in Fig. 4.

The standard bicarbonate (Fig. 28) was changed in a similar way in the different groups both at ex. OP and at ex. III. The increase at ex. IV in group C showed a probably significant difference from the decrease in H and Se.

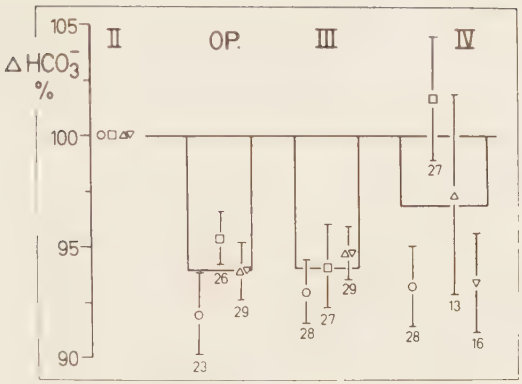


FIG. 28.—Relative values (M ± SEM) for standard bicarbonate at peroperative ex. OP, and at postoperative ex. III and IV in the anaesthetic groups. Symbols as in Fig. 4.

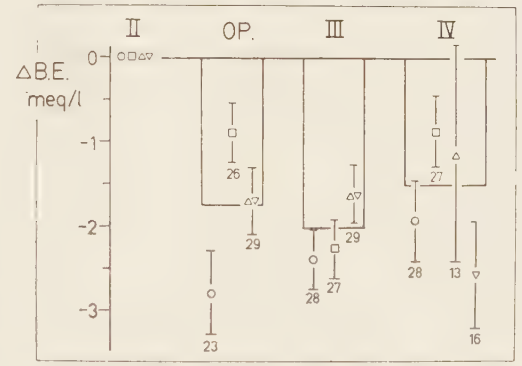


FIG. 29.—Relative values (M ± SEM) for arterial base excess at postoperative ex. III and IV in the anaesthetic groups. Symbols as in Fig. 4.

The arterial base excess (Fig. 29) was significantly less reduced in group C than in group H at ex. OP.

2.6. RESULTS RELATED TO ADEQUATELY REPLACED PER- AND POSTOPERATIVE BLOOD LOSS

In order to estimate the importance of haemorrhage in some of the parameters investigated, groups of 30 patients each were chosen from the series:

A_{bl} III = those in whom the greatest blood loss was noted at ex. III,
B_{bl} III = those in whom the least blood loss was noted at ex. III,
A_{bl} IV = those in whom the greatest total blood loss was noted at ex. IV, and
B_{bl} IV = those in whom the least total blood loss was noted at ex. IV.

The blood losses were adequately replaced. The relative haemoglobin concentrations, as related to those measured preoperatively, and also the mean age of the patients, their blood losses and replaced blood losses are shown in Table 48. The distribution of the patients of these groups according to the form of anaesthesia given is shown in Table 49. The results are summarized in Tables 50–52.

As has been shown in Table 49, the patients in the A_{b1} and B_{b1} groups were distributed unevenly among the anaesthetic groups. As has been pointed out earlier (2.5), different types of anaesthesia have different effects upon several of the parameters investigated. In an attempt to isolate the effects of large and small blood losses, adequately replaced, from the effects of various types of anaesthesia, two groups of 30 patients each were selected from the series. These groups consisted, respectively, of the ten patients with the smallest and the ten patients with the greatest peroperative blood loss from each of the three anaesthetic groups, and are called b_{b1} and a_{b1}, respectively. The peroperative blood losses in the two groups were 364 $\pm$ 26 and 1530 $\pm$ 212 ml[1]). Thus as regards blood loss, the difference between groups a_{b1} and b_{b1} is only non-significantly less than between groups A_{b1}III and B_{b1}III. The results of comparisons between the changes in some parameters in groups a_{b1} and b_{b1} are shown in Table 53. Except for $\dot{V}_{O_2}$ no significant differences between the changes in these groups were found.

A. *Oxygen uptake*

The oxygen uptake was increased at ex. III, significantly more in group A_{b1} III than in group B_{b1} III.

The rectal temperature changed in a similar manner in all groups.

B. *Oxygenation of blood*

1. Ventilation

The arterial carbon dioxide tension changed equally and no differences were noted.

The pulmonary ventilation increased to a probably greater extent in group A_{b1}III than in group B_{b1}III.

2. Alveolo-arterial oxygen transport

The arterial oxygen tension decreased somewhat more in groups A_{b1}III and A_{b1}IV than in groups B_{b1}III and B_{b1}IV.

The alveolo-arterial oxygen difference increased to essentially the same extent in the different groups.

The physiological dead space increased in group A_{b1}III, in contrast to a decrease in group B_{b1}III.

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[1]) M $\pm$ SEM.

The physiological dead space/tidal volume ratio decreased similarly in groups A_{b1}III and B_{b1}III and increased in groups A_{b1}IV and B_{b1}IV.

The shunt blood flow/cardiac output ratio showed the greatest increase in groups B_{b1}III and B_{b1}IV, but the differences between these changes and those in groups A_{b1}III and A_{b1}IV are not statistically significant.

C. *Oxygen transport in blood*

The changes of the *haemoglobin concentration* in the different groups are shown in Table 48.

The arterial oxygen saturation decreased in all groups.

The mixed venous oxygen saturation showed a decrease in group A_{b1}III, which differs significantly from the unimportant change in group B_{b1}III.

The arterio-venous oxygen difference increased in the A_{b1} groups and decreased in the B_{b1} groups. Only at ex. III was there a significant difference between the changes.

The cardiac output increased to a somewhat greater extent in the B_{b1} groups than in the A_{b1} groups, but the difference was not statistically significant.

The available oxygen was increased to essentially the same extent in the different groups at ex. III. At ex. IV there was a probably significant difference between the changes in the A_{b1} and B_{b1} groups.

The oxygen utilization coefficient showed a significantly greater increase in group A_{b1}III than in group B_{b1}III.

D. *Acid-base balance in arterial blood*

The arterial base excess was decreased similarly in the different groups at the postoperative examinations.

Chapter 3

DISCUSSION

The aim of the present investigation was to study and evaluate the short-term biological and clinical reactions to a few different types of anaesthesia and an extensive operative procedure in elderly patients. Ideally, a homogeneous group of patients should be chosen for this purpose, and each type of anaesthesia as well as the operative and other therapeutic procedures should be as consistent and stereotyped as possible. Male patients treated by prostatectomy were chosen according to certain criteria, but it was unavoidable that certain biological factors of a predisposing character were inconsistent in the group of patients, e.g. the level of respiratory and circulatory functional capacities. The influence of such factors must therefore be considered separately. Also, certain therapeutic factors varied in different patients, e.g. blood loss and blood replacement or duration of operation, and must be considered separately.

The question may be asked whether the findings at the preoperative examinations were truly representative of the daily condition and function of the patients, as elderly patients are known to react sometimes to hospitalization with a state of stress, they become more anxious than usual and even show psychotic symptoms (Knox, 1961)[75]. This must be considered, especially when the operation is believed by the patients to be severe and hazardous, as in the present case. The clinical impression was that a few of the patients investigated were nervous and tense but not considerably so, and there were no psychotic symptoms.

As an example, the effect of preoperative tenseness may be estimated from basal oxygen uptake measurements. Such measurements were made at ex. I, a few days before operation, and at ex. II on the morning of the day of operation, under otherwise essentially identical circumstances. The oxygen uptake was significantly higher at ex. II, in corroboration of earlier observations (Troell, 1952)[131]. For this reason, the result at ex. I was taken to be the representative "basal" value, and was also used in different individual calculations instead of the predicted "basal" oxygen uptake value.

It was considered important to counteract stress in the patients by developing personal contact with them in their homes before hospitalization, or in the out-patient department of the hospital. During their stay in the hospital the author paid regular visits—at least once daily—to each patient. They were fully informed of the examination to be made, and their free consent was obtained initially by the author and later confirmed by the surgeon-in-charge of the ward. They were also trained in certain laboratory procedures, such as breathing through a mouth-piece and valve while wearing a nose-clip. Nevertheless,

to judge from observed values of Pa_{CO_2} and $\dot{V}_E$, some of the patients hyperventilated during the respiratory examinations.

In order to make comparisons more valid, the results of the different examinations have been presented in general, both in absolute and in relative terms, e.g. as change from ex. II (occasionally ex. I).

Clinical observations indicate that at the immediately postoperative examinations (III and IV) the patients were not in a somatic or psychic steady state. This seems to be unavoidable due to the declining effect of anaesthesia and various effects of the operative trauma. It must be concluded thus that some measurements, e.g. of circulatory function, were less representative and precise than at the other examinations. The author's impression, confirmed by other members of the medical staff in contact with the patients, was that the patients very willingly and actively cooperated in the examinations and that they did not look upon the project as a considerable extra burden. If this was, in fact, true, it may be attributed greatly to the good personal contact which usually developed between the patients and the author.

3.1. PREOPERATIVE CONDITION

The preoperative values of the investigated parameters are reported in Tables 5–32. Tables 54–56 present values obtained from the literature of some corresponding parameters in similar series of patients. A detailed comparison of the different series is of doubtful value, since in many cases they differ as to selection, examination conditions and methods.

The oxygen uptake in this study appears to be directly comparable with the values reported from other investigations. The pulmonary ventilation was also well within the normal limits given by other authors. The alveolar ventilation was of the same magnitude as that reported by Tenney & Miller (1956)[132]. The respiratory rate was somewhat lower in the present series than in most other studies. The tidal volume was essentially the same as that reported by other authors. The dead space was determined by various methods in the different studies, and the values vary greatly. The value obtained here appears reasonable. The arterial carbon dioxide tension was the same in this study as the highest reported by other authors. It should be pointed out again that the patients described here were not premedicated before their preoperative examination.

The arterial oxygen tension was lower than that reported from other series and the alveolo-arterial oxygen tension gradient somewhat higher. The arterial oxygen saturation, however, did not differ from that in other investigations. The mixed venous oxygen saturation was lower than in the study by Granath & Strandell (1964)[51] on healthy old men and corresponds better to the values reported by Irnell (1964)[70] and Troell (1952)[134]. Their results were obtained from asthmatic patients and patients belonging to risk group III according to Gordh (1949)[48], respectively. The oxygen content of arterial blood was somewhat lower in this study than in those by Irnell (1964)[70] and Troell (1952)[134]. The arterio-venous oxygen difference was greater than in the series of Troell (1952)[134], and corresponds better to the values given by Irnell (1964)[70] and Granath et al. (1964)[50]. The cardiac output was lower than

that reported by Granath et al. (1964)[50] as valid for healthy old men in the recumbent position. Further, it was about 20 per cent lower than that found by Troell (1952)[134] in patients belonging to the highest risk group, but greater than in the asthmatics examined by Irnell (1964)[70]. The shunt blood flow cardiac output ratio was considerably lower than that calculated by Ward et al. (1966)[139]—the difference is probably largely explainable by different methods of calculation.

In so far as it is possible at all to compare the different reports discussed, it may be summed up that the values obtained in the present study are well comparable with those given by other investigators. A special comment may be required as to the somewhat high physiological dead space tidal volume ratio, the low mixed venous oxygen saturation and the low haemoglobin concentration. However, it must be taken into consideration that this series included both patients with essentially normal hearts and lungs and patients with heart and or lung diseases, as compared with the patients in, for instance, the studies of Strandell and co-workers (1964)[50, 51, 126, 127]. Further, the patients described here were afflicted with a surgical disease, which probably reduced their physical activities and in this or some other way influenced the parameters investigated.

From comparison with other studies it seems probable that at the preoperative examinations the patients described here were in equally basal conditions as the patients of the other series. This finding justifies the use of relative instead of absolute values when reporting postoperative changes of the parameters investigated. Relative values have been used for estimations of the influence of different types of anaesthesia, of the amount of blood loss, adequately replaced, and of the patients' ages and their ventilatory and circulatory functions.

3.2. POSTOPERATIVE CHANGES

A. *Oxygen uptake*

The oxygen uptake was, on an average, 42 per cent greater at ex. III than preoperatively. At ex. IV it was still greater (+ 22 per cent) than preoperatively. The values from these postoperative examinations varied widely. The greatest oxygen uptake was probably not recorded in all the patients; in ex. III, for instance, several patients were still not quite awake after general anaesthesia (cf. Shackman et al. 1951)[114], or the effects of the nerve blocks persisted. It is evident from Fig. 4 that the patients in group C had the most increased oxygen uptake at ex. III; on this occasion these patients were more awake than those in group H. The smallest increase was noted in group S—these patients were totally or practically totally free from pain due to persistent effects of the nerve block. The difference between the changes in groups C and S is probably significant. It would seem that neither the preoperative circulatory function nor the age of the patients

was of conclusive importance for the postoperative changes of the oxygen uptake. On the other hand, the patients with the largest peroperative blood losses showed a significantly greater increase of the oxygen uptake at ex. III than those with the smallest peroperative blood losses.

At ex. IV there were no significant differences between the groups examined as to oxygen uptake. The smallest change was shown by patients with residual effects of nerve blocks, but the difference between this group (Se) and the other anaesthetic groups was small.

Hobsley (1963)[65] reports that the oxygen uptake is somewhat lower one hour postoperatively than preoperatively. The type of anaesthesia used and the degree of wakefulness of the patient are not clear from his report. Ellison et al. (1966 [37] examined patients 20–70 hours postoperatively and found no change in oxygen uptake, compared with the preoperative values.

Postoperative increases of the oxygen uptake are reported by Harild (1941 [60]. Troell. 1952 [134] found that the oxygen uptake was increased postoperatively only in those patients who constituted the greatest surgical risk. Significant increases at repeated examinations 2–24 hours postoperatively were also established by Carlsten et al. (1954)[27]. It should be pointed out, however, that in their investigation the preoperative oxygen uptake—i.e. the reference level—was very low, probably because the patients were influenced by barbiturates at that time. 2–9 hours postoperatively the oxygen uptake in their study was somewhat lower than the predicted preoperative values. Bay et al. (1968)[12] found that the oxygen uptake was increased postoperatively only in patients who showed distinct shivering, but that the increase was then sometimes pronounced. In the investigation presented here the relationship between shivering and hypermetabolism was not studied. However, the greatest increase of oxygen uptake occurred in patients without shivering.

In this study, comparatively high values for the postoperative oxygen uptake were obtained. The highest value was 848 ml O_2 STPD/min (case 33 at ex. III). For patients such as those studied here such high values can be at the upper limit of long term capacity of the oxygen transporting system.

What then causes this relatively large increase in the metabolism?

Influence of age

Troell (1952)[134] observed an increase in the oldest patients of his study. In the study presented here the patients were older than those in the investigations mentioned above. The importance of age is confirmed by the finding of Goldberg et al. (1965)[47] that elderly patients showed greater heat losses during anaesthesia than younger ones. A negative correlation between postoperative body temperature and the age of the patients was pointed out by Lewis & Welch (1965)[78]. According to Rolly (1965)[106], considerable increases in the metabolism occur during rewarming of patients after hypothermia; during active rewarming, $\dot{V}_{O_2}$ at a body temperature of 34–35°C was about 23 per cent

greater than during normothermia. In combination with the results reported here, these findings appear to support the assumption that elderly patients show a greater increase in oxygen uptake postoperatively than younger patients. The increased metabolism may probably be due to some extent to increased endogenous heat production for homeostasis.

Influence of degree of wakefulness

Group C showed the greatest increase in oxygen uptake at ex. III among the anaesthetic groups. Five of the six patients with a postoperative value exceeding 250 ml O_2 STPD/min. m^2 BSA belonged to group C. In Troell's investigation (1952)[134] the patients discussed above—in contrast to the others in his series—had without exception been anaesthetized with O_2-N_2O-muscle relaxants. As Boutros (1965)[22] has shown, patients are more awake immediately after curare anaesthesia than after some other types of anaesthesia investigated. Muneyuki et al. (1968)[91] observed a reduction in oxygen uptake when analgesia was instituted postoperatively. These findings support the opinion that the degree of wakefulness—or strictly the sense of pain —may be a contributing factor to the increased metabolism postoperatively.

Influence of blood loss

As can be seen in Tables 50 and 53, the patients with the greatest total blood loss showed the greatest increase in oxygen uptake at ex. III. The blood losses were replaced by whole blood and/or occasionally dextran solutions in adequate amounts. Nahas et al. (1966)[92] noted a significant increase of the oxygen uptake in dogs after blood losses corresponding to 25 ml/kg body weight, the raised value still persisting 90 minutes after retransfusion. The authors ascribe this finding to the effects of an increased liberation of catecholamines.

B. *Oxygenation of blood*

1. Ventilation

The ventilation at the postoperative examinations, as expressed by Pa_{CO_2}, was essentially adequate. However, there were great interindividual variations, especially at ex. III, when Pa_{CO_2} was probably significantly increased in spite of the increases of $\dot{V}_E$ and $\dot{V}_A$. Thus, the increase of the ventilation was on this occasion proportionally smaller than the increase of the carbon dioxide excretion (under certain conditions roughly related to the metabolism).

Of the different anaesthetic groups hypercapnia only occurred after halothane anaesthesia with spontaneous ventilation.

The oldest patients had a decreased Pa_{CO_2} at ex. III and differed in this from the younger patients in the study.

It would seem that the preoperative ventilatory capacity did not play any decisive role in the changes of ventilatory parameters noted at ex. III or IV.

Some postoperative ventilatory studies in comparatively younger patients have been reported. Thus, STEPHEN & TALTON (1964)[123] found no changes of $\dot{V}_E$, f, V_T or Pa_{CO_2}. HAMILTON et al. (1964)[59] examined patients of varying ages 1–48 hours after different surgical operations under varying types of anaesthesia, and found no essential changes of f or Pa_{CO_2}. However, the authors diagnosed "hypoventilation" in 5 out of 27 patients, basing their opinion on lung X-rays. An average increase of Pa_{CO_2} by 18 per cent at examinations 0.5–1 hour postoperatively is reported by Hobsley (1963)[65], who at this time also found decreases of $\dot{V}_A$ by as much as 50 per cent. MARSHALL & MILLAR (1965)[84] found an increase of Pa_{CO_2} after major but not after minor surgical operations, with reversion to the preoperative level within three hours. Postoperative Pa_{CO_2} values exceeding 45 mm Hg were observed in 25 per cent of patients reported by HAMILTON & DEVINE (1957)[58]. LEWIS & WELCH (1965)[78] found no significant changes of Pa_{CO_2} or $\dot{V}_E$ postoperatively, but they did observe decreases of V_T and increases of f.

Influence of type of anaesthesia

Hypercapnia after halothane anaesthesia with spontaneous ventilation has been reported by HOLMDAHL & PAYNE (1960)[68], TAYLOR et al. (1964)[131], and COLGAN & WHANG (1968)[32], among others. TAYLOR et al. as well as IVANOV et al. (1967)[71] state that Pa_{CO_2} returns to normal within 30 minutes after termination of the anaesthesia. Thus, as the Pa_{CO_2} is rapidly normalized, it will be inappropriate to speak of postoperative hypoventilation in these connections, in spite of an elevated Pa_{CO_2}. A simultaneous increase of the respiratory exchange ratio indicates a ventilatory emptying of carbon dioxide stores, which have been augmented during anaesthesia. In the present study, there was a moderate increase of R at ex. III, but there were no differences between the various anaesthetic groups.

After operations in the upper part of the abdomen under O_2-N_2O-muscle relaxant anaesthesia BRATTSTRÖM (1954)[24] found increases of $\dot{V}_E$ and f, and in no case signs of ventilatory insufficiency. DAM & GULDMAN (1959)[34] observed ventilatory insufficiency in 1.4 per cent of patients after anaesthesia with d-Tubocurarine. BOUTROS (1965)[22] noted a slight increase of Pa_{CO_2} in men one hour after curare anaesthesia. In the series presented here Pa_{CO_2} was unchanged in group C at ex. III and IV.

MILLAR & MARSHALL (1965)[88] report a non-significant increase of Pa_{CO_2} after anaesthesia with controlled ventilation as well as after anaesthesia with spontaneous ventilation.

Elevated Pa_{CO_2} values (+17 per cent) immediately after operations under spinal anaesthesia are reported by LINDERHOLM & NORLANDER (1958)[80]. However, their patients had sleeping doses of barbiturates. In their study Pa_{CO_2}

had reverted to the preoperative level 24 hours after the operation. In elderly patients Ward et al. (1966)[139] found no changes in Pa_{CO_2} 24 hours after transurethral resections under spinal anaesthesia. After operations under spinal nerve blocks, Pa_{CO_2} was constantly reduced postoperatively in the series presented here.

Influence of age

Lewis & Welch (1965)[78] found that postoperative Pa_{CO_2} was negatively correlated to the age of the patients. Marshall & Millar (1965)[84] found lower Pa_{CO_2} values one hour postoperatively in older patients than in younger ones. These results are confirmed in this investigation.

It is conceivable that this circumstance is due to a more pronounced hypoxic drive on the ventilation in the older patients. The mean Pa_{CO_2} and Pa_{O_2} values in groups A_{age} and B_{age} at ex. II and III are given in Fig. 30. From this figure it is evident that Pa_{O_2} of the older patients at ex. III was not significantly lower than that of the younger ones. However, this does not exclude the possibility that the difference between the Pa_{CO_2} changes can be due to different degrees of hypoxic drive in the two age groups. No close analysis of this question was made.

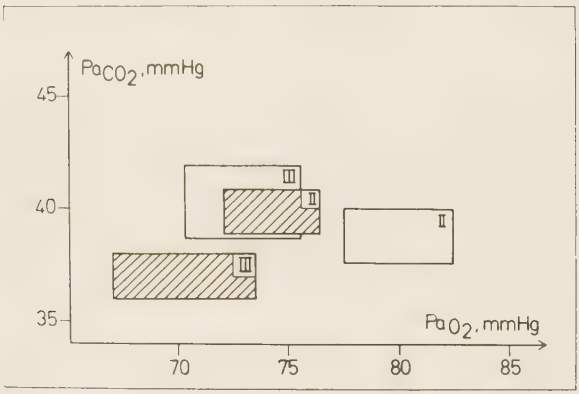

Fig. 30.—Pa_{CO_2} (M ± SEM) and Pa_{O_2} (M ± SEM) at preoperative ex. II and postoperative ex. III in the age groups A (/// »older«) and B (□ »less old«).

Influence of pain

The influence of the degree of wakefulness and of pain upon the postoperative oxygen uptake has been discussed above.

It is very likely that the residual anaesthetic effect at ex. III allowed a better PEF in group S than in groups H and C. The low values in group H can probably also be explained partly as due to insufficient wakefulness and cooperation. At ex. IV the anaesthetized patients in group Se showed a significantly smaller decrease in PEF than those in groups H and C.

Corresponding decreases of the ventilatory capacity after intra-abdominal operations have been reported by Anscombe (1958)[4], among others. Favour-

able effects of prolonged epidural blocks on the postoperative ventilation were observed by Cleland (1949)[29] and Simpson et al. (1961)[117], and on postoperative pain by Green & Dawkins (1966)[52].

Even though the decrease of the ventilatory capacity, in this study expressed as PEF, and the increase of the ventilation separately may seem moderate, the combination implies that a comparatively much greater part of the maximal ventilatory capacity is required postoperatively. This should, of course, be taken into consideration during postoperative care, when the ventilatory capacity can be increased by nerve blocks.

2. Alveo-arterial oxygen transport

Postoperatively there was a mean decrease of Pa_{O_2}. In group S, however, there was an increase, though non-significant. It would seem that the blood loss, although adequately replaced, was of some importance in this respect. On the other hand, the preoperative ventilatory and circulatory status of the patients did not influence the Pa_{O_2} changes. Nor did the age of the patients in these high age groups appear to be of importance in this connection.

That Pa_{O_2} is reduced postoperatively has long been known. In the older Swedish studies only Sa_{O_2} was examined. Troell (1952)[134] found the lowest values in patients of the highest risk group, and Carlsten et al. (1958)[27] found that postoperatively Sa_{O_2} decreased continuously until 18–24 hours after operation.

Gordh et al. (1958)[49] found that 24 hours postoperatively, Pa_{O_2} was 11.8 mm Hg lower than preoperatively. Lewis & Welch (1965)[78] found a non-significant, continuous decrease of Pa_{O_2} up to 24 hours postoperatively (−10.3 mm Hg). For further references, see Laver & Seifen (1965)[77].

Influence of age

Postoperatively, Pa_{O_2} is reported to be lowest in the oldest patients. Thus Nunn (1963)[96] reports the correlation coefficient between postoperative Pa_{O_2} and the patient's age to be −0.491 and the regression equation to be: Postoperative Pa_{O_2} = 94.3 − 0.455 (age). Applied to the present series the equation gives a mean of 61.0 mm Hg, which can be compared with 69.7 mm Hg obtained at ex. III and 73.9 mm Hg at ex. IV, in the present study. Fairley et al. (1968)[42] state that Pa_{O_2} 15 minutes postoperatively is 81–0.25 (age), which for the present series gives a mean of 62.7 mm Hg. Marshall & Millar (1965)[84] report that postoperatively Pa_{O_2} shows the greatest decrease in old patients, in whom they found a decrease of 14 mm Hg 15 minutes postoperatively—a change greater than that obtained in this study (−7.6 mm Hg). After the first 24 hours postoperatively, however, Marshall & Millar (1965)[84] found an increase of 1.9 mm Hg in contrast to the persisting decrease in this investigation (−3.4 mm Hg).

Influence of preoperative ventilatory status

More pronounced and prolonged decreases of Pa_{O_2} postoperatively in patients with impaired lung function are reported by Marshall & Millar (1965)[84]. In this respect it was not possible in the present study to state whether there were any definite differences between patients with normal and patients with moderately impaired lung function.

Influence of type of anaesthesia

In this study, groups H and C showed reductions of Pa_{O_2} at ex. III, in contrast to group S. Results from studies by other authors of Pa_{O_2} within one hour after different types of anaesthesia are summarized in Table 57. The table shows that the results from the present study are comparable to those from the other investigations presented.

It is not intended to discuss the causes of the postoperative changes of Pa_{O_2}. The changes found in this investigation appear to be similar to those observed in many other studies, although there are reasons to believe that the series differ as regards age, amount of blood loss and type of anaesthesia used. How, then, can the comparatively slight changes of Pa_{O_2} be explained?

Old men are more prone to local, alveolar collapses than young ones, according to Edelman et al. (1968)[36]. These authors also found that old men can "improve their uniformity of ventilation" by increasing their tidal volume. In the study presented here, V_T was increased postoperatively, which gave prerequisites for improvements of "uniformity of ventilation" and oxygenation of blood.

The hypotheses of Nahas et al. (1966)[92] of an increased liberation of catecholamines after bleeding and retransfusion has been mentioned above. According to Kreuzer (1961)[76], after catecholamine injections in anaesthetized dogs Pa_{O_2} increases. Reduction of the haematocrit in anaesthetized dogs also causes an increase of Pa_{O_2}, according to Cain (1965)[26]. Kennedy et al. (1968)[74] claim that spinal anaesthesia in the presence of acute blood loss is associated with reductions of Pa_{O_2}, in contrast to conditions during spinal anaesthesia in normovolemic states. In any case, it would seem very likely that apart from the fairly advanced age of the patients and the use of spinal nerve blocks, the averagely large, although replaced, blood losses can also have contributed to the smallness of the Pa_{O_2} decreases in this study.

V_D was increased postoperatively. The increase at ex. III was probably significant in groups C and S, but not in group H, which finding must be seen in relation to the changes of V_T. It would seem that the amount of preoperative blood loss, even when adequately replaced, is of importance in this respect. Increases of V_D after unreplaced blood losses are discussed by Nunn & Freeman (1964)[97].

V_D/V_T was changed only at ex. IV, and then only in groups H and C. In contrast to the case of V_D, the amount of replaced blood loss is without

significance. On the other hand, the preoperative ventilatory function is probably of importance for the changes of V_D/V_T at the postoperative examinations.

Askrog et al. (1964)[6] observed progressive increases of V_D as well as of V_D/V_T during different types of anaesthesia. Cooper (1967)[33] found that the increases of V_D during anaesthesia were more pronounced in old patients. On the basis of the results of N_2 wash-out studies, Brattström (1955)[24] suggested that postoperatively the functional dead space is decreased.

No definite concepts of the changes in the physiological dead space can be formed from this study. The validity of the results is diminished by the fact that the assumption $a\text{–}AD_{CO_2} = 0$, which is a premise for Bohr's formula, was probably never fulfilled. All the same, the results can be considered to express that no changes of V_D of clinical importance occurred.

The shunt blood flow/cardiac output ratio was found to be increased postoperatively. The increase at ex. III is significant only in group H, and at ex. IV probably significant only in group Se. Further, the increase is a little more pronounced in the patients with the smallest blood losses, and in those with the poorest preoperative ventilatory status. Age and preoperative circulatory status are of secondary importance in this connection.

In the investigation of Gordh et al. (1958)[49] the shunt calculated from $A\text{–}aD_{O_2}$ increased from a preoperative value of 11.7 per cent to 15.5 per cent 24 hours postoperatively, a mean increase of 33 per cent. Unchanged shunting after halothane anaesthesia is reported by Colgan & Whang (1968)[32]. A shunt decreased by 32 per cent 24 hours after transurethral resection under spinal anaesthesia is reported by Ward et al. (1966)[139]. Hobsley (1963)[65] found that the shunt, calculated in a similar way, was smaller 0.5–1 hour postoperatively than preoperatively in patients with healthy lungs. The reverse conditions prevailed in patients with lung disease.

In the total series the ventilation-perfusion ratio was found to be significantly increased postoperatively. It is worthy of note that the increase at ex. III is significant only in group C of the anaesthetic groups. On this occasion $\dot{V}_A$ showed similar changes in these groups. Therefore, the increased $\dot{V}_A/\dot{Q}$ value in group C must be explained by a too small increase of the cardiac output—a relative "hypoperfusion".

C. Oxygen transport in blood

The mixed venous oxygen saturation was greatly decreased. Immediately postoperatively the changes were most pronounced in group C and small in group S. Differences between the changes in groups A_{bl} and B_{bl} were also noted.

The arterio-venous oxygen difference was greatly increased in group C at ex. III. Despite adequate replacement, the amount of peroperative blood loss

appears to be of some importance for this parameter also. Age and the preoperative circulatory status are of minor importance.

Considerable increases of AVD_{O_2} at examinations on the first postoperative day were noted in several cases by HARILD (1941)[60]. On a corresponding occasion CARLSTEN et al. (1954)[27] found non-significant increases. In the earlier postoperative period significant decreases were observed by CARLSTEN et al. (1954)[27], and an unchanged or decreased AVD_{O_2} by TROELL (1952)[134].

Significant increases of the cardiac output were noted in the present study. In relation to the increase of $\dot{V}_{O_2}$ the increase of $\dot{Q}$ was a little greater than that found by GRANATH et al. (1964)[50] in healthy old men during supine work. Considering that the present series included many patients with heart disease (see part II), this fact may seem notable, seeing that $\dot{Q}$ increases less in persons with heart disease than in those with normal hearts when $\dot{V}_{O_2}$ increases (cf. HICKAM & CARGILL, 1948)[62]. In the present study, however, the preoperative circulatory status of the patients was not proved to be of any significance for the changes of the central circulation at the postoperative examinations.

In several cases the circulation immediately after anaesthesia with O_2-N_2O-d-Tubocurarine followed by decurarization with atropine and neostigmine became distinctly hypokinetic compared with the relations between $\dot{V}_{O_2}$ and $\dot{Q}$ reported by GRANATH et al. (1964)[50]. Also compared with the conditions in group H and particularly in group S, the circulation in group C was hypokinetic at ex. III (Fig. 31).

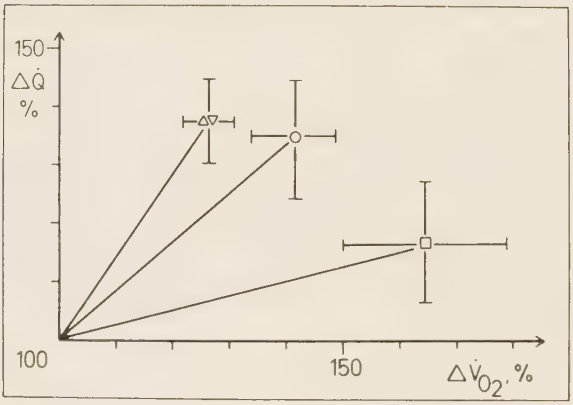

FIG. 31.—Relative values (M±SEM) for cardiac output and oxygen uptake at postoperative ex. III in the anaesthetic groups. Symbols as in Fig. 4.

The following findings from earlier examinations of the cardiac output in the postoperative period may be mentioned: HARILD (1941)[60] found an essentially unchanged $\dot{Q}$ on the first day postoperatively, with a simultanous increase in $\dot{V}_{O_2}$ of about 20 per cent. Unchanged cardiac outputs in the early postoperative period were also reported by REID et al. (1967)[102]. TROELL (1952)[134] noted a significant increase of $\dot{Q}$ 6–8 hours postoperatively in the

patients constituting the greatest surgical risk. At repeated examinations 2–24 hours postoperatively Carlsten et al. (1958)[27] found significant increases of $\dot{Q}$. However, in their investigation $\dot{Q}$ was low preoperatively (M = 4.15 l/min), and the highest value reported (M = 6.4 l/min, 5–9 hours postoperatively) is somewhat lower than the highest in this study (M = 6.53 l/min at ex. III). Heilbrunn & Allbritten (1960)[61] found an increase of $\dot{Q}$ by 9.5 per cent immediately after various intra- and extrathoracic operations. On the first day postoperatively, however, $\dot{Q}$ was 6.6 per cent lower than preoperatively. Clowes et al. (1960)[30] reported a consistently lower $\dot{Q}$—compared with preoperative conditions—during the first 24 hours after major intra-abdominal operations.

A decrease of $\dot{Q}$ during high epidural anaesthesia is described by McLean et al. (1967)[85], among others.

The increase of $\dot{Q}$ in this series may seem great, but the series probably differs from those mentioned above with regard to the age of the patients, their preoperative status and per- and postoperative blood losses.

$\dot{V}_{O_2}$ increased more in these old patients than in younger patients of other studies, and thus $\dot{Q}$ should also have increased more. The circulation in old patients is even normally hypokinetic compared with that of younger ones, so that old patients do not have the prerequisites for compensating increases of $\dot{V}_{O_2}$ by increases of AVD_{O_2} to the same extent as younger ones. This holds also for patients with impaired cardiac function.

Significant reductions of the haematocrit were observed at ex. III and IV. According to Cain (1964)[26], reductions of hct in anaesthetized dogs bring about an increase of $\dot{Q}$. The observed reductions of Ca_{O_2} might thus have contributed to the increases of $\dot{Q}$ (cf. Nunn & Freemann, 1964)[97].

Some patients were subjected to some overtransfusion, by which $\dot{Q}$ may have been increased due to improved venous distension on the right side of the heart.

The notion "available oxygen" was suggested and discussed by Nunn & Freeman (1964)[97]. These authors state that a value for $\dot{C}a_{O_2}$ of 300 ml/min "is rapidly fatal" and that "400 ml/min is the lowest rate which should be tolerated for a short period during anaesthesia". On the basis of these opinions, some of the findings in the present study are worthy of note:

One patient had a preoperative $\dot{C}a_{O_2}$ value of 417 ml/min ($\dot{V}_{O_2}$ = 224 ml STPD/min, $S\bar{v}_{O_2}$ = 43.3 per cent and O_2uc = 53.7 per cent) and eleven patients in all had a $\dot{C}a_{O_2}$ value below 650 ml/min. In another patient, $\dot{C}a_{O_2}$ postoperatively was found to be 311 ml/min ($\dot{V}_{O_2}$ = 198 ml STPD/min, $S\bar{v}_{O_2}$ = 33.2 per cent and O_2uc = 63.8 per cent) and in nine patients in all it was lower than 650 ml/min—in two of them lower than 500 ml/min. Postoperatively, the relative values for HCO_3^- and B.E. were essentially the same in these patients as in the others in the series.

In the total series $\dot{C}a_{O_2}$ was found to be increased postoperatively, but in the different anaesthetic groups significant increases occurred only in group S

at ex. III. At ex. IV there was an increase in group $B_{bl}IV$ and a decrease in group $A_{bl}IV$.

At the postoperative examinations O_2uc was increased. The increase at ex. III was almost exclusively attributable to group C, but the amount of blood loss, adequately replaced, may also be of importance. As remarked by Nunn & Freeman (1964)[97], O_2uc increases with increasing $\dot{V}_{O_2}$. Consequently the differences in the changes of O_2uc in groups $A_{bl}IV$ and $B_{bl}IV$ and also between (a) groups H and S combined, and (b) group C are probably to some extent due to different changes of $\dot{V}_{O_2}$. The mean changes of O_2uc were probably within the normal limits, but curare anaesthesia—as given here—, and adequately replaced, large blood losses probably resulted in comparatively large increases of O_2uc, however.

In spite of the fact that several patients showed a low $\dot{C}a_{O_2}$ and had an O_2uc exceeding 60 per cent, as far as is known none of the patients acquired myocardial or central nervous lesions that could be ascribed to hypoxia in the immediate postoperative period (cf. part II). This may partly be ascribed to a centralization of the circulation as described in asphyxia by Scholander & Elsner (1968)[110] and in apnoeic oxygenation by Holmdahl (1956)[66] as well as to a locally reduced metabolism induced by anaesthesia and reduced temperature.

D. *Acid-base balance in arterial blood*

pH_a was decreased. In the different anaesthetic groups the decrease at ex. III was significant in groups H and C, and at ex. IV probably significant in group H.

Hobsley (1963)[65] found a mean decrease in pH_a of 0.096 pH-units 0.5–1 hour after major surgical procedures, whereas the decrease after minor operations was 0.043 pH-units. Considerably greater changes are reported by Lewis & Welch (1965)[78], who 1–3 hours after intra-abdominal operations found average decreases of 0.4 pH-units. In the latter study the postoperative pH was correlated positively to the age of the patients.

Linderholm & Norlander (1958)[80] and Lewis & Welch (1965)[78] found slight increases of pH_a 24 hours postoperatively. Corresponding increases 24 hours after operations on old men performed under spinal anaesthesia are reported by Ward et al. (1966)[139], while Millar & Marshall (1965)[88] found unchanged pH_a values after halothane anaesthesia with spontaneous ventilation.

pH_a changes immediately after different types of anaesthesia, as reported in the literature, are summarized in Table 58.

HCO_3^- was decreased postoperatively. The decrease at ex. IV mainly concerned groups H and Se.

HCO_3^- changes immediately after different types of anaesthesia, as reported in the literature, are summarized in Table 59. Linderholm & Nor-

LANDER (1958)[80] found a slight increase of HCO_3^- 24 hours postoperatively. However, in their study the values from the preoperative examinations are fairly low (M = 21.9 mEq/l).

The decrease of B.E. at ex. III is probably significantly greater in the older patients than in the somewhat younger ones. At ex. IV the decrease was mainly attributed to groups H and Se.

The acid-base balance in arterial blood indicates the presence of a slight metabolic acidosis in the postoperative period. Generally the patients did not compensate for this by a sufficiently increased ventilation.

However, pH_a was not more changed in these elderly patients than in the younger ones in the studies referred to. On the other hand, the duration of the acidosis was perhaps longer in these patients.

As has been discussed earlier, older patients show a tendency to hyperventilation postoperatively, which may explain—taking into consideration the averagely large blood transfusions—the fairly small pH_a changes in these patients.

Chapter 4

CLINICAL IMPLICATIONS

All observations made in a clinical investigation cannot be reported numerically. Subjective estimations—with their inherent flaws—must therefore be considered a necessary complement.

Measures taken to prevent an increase of postoperative metabolism must be regarded as most essential for the maintenance of a tolerable level of the performance of the oxygen transporting system in elderly patients. As shown in section 2.6 the amount of blood loss, even with adequate replacement, is probably significant for the postoperative oxygen uptake, and consequently the blood losses should be kept as low as possible. This is, of course, obvious in clinical practice, and should hold good for both the peroperative and the postoperative periods. No definite inferences can be drawn from the present investigation as to the possibilities of an anaesthetist to reduce the per- and postoperative blood loss. Fig. 3 suggests, however, that anaesthesia with O_2-N_2O-d-Tubocurarine with controlled ventilation may be associated with a tendency to greater blood losses than the other types of anaesthesia used. However, the arterial and/or venous blood pressure level is probably of greater importance for the amount of peroperative blood loss than the type of anaesthesia. It has not been possible to claim an unequivocal relationship between peroperative arterial blood pressure changes and blood losses in this study. In this series of patients it was a constant aim to replace blood losses immediately and completely. In this way reductions of the circulating blood volume were probably avoided, which can possibly have contributed to the averagely high blood losses in this series compared with other comparative series.

The smallest postoperative blood loss occurred during prolonged, continuous epidural anaesthesia. The influence of pain on the patient seemed to be of great importance for the postoperative bleeding. Even if it is likely that postoperatively there are complex relationships between oxygen uptake, bleeding and influence of pain, routine measures should be taken to reduce all three of them.

The influence of pain was sometimes obvious. It is the author's impression that an important cause of the confusion shown by some patients immediately after prostatectomy is to be found in this factor. Thus active combating of pain is desirable not only for humanitarian but also for physiological and nursing reasons. Experiences from this study indicate that a postoperatively prolonged

continuous epidural anaesthesia may be a satisfactory method. When the block is prolonged for about 17 hours postoperatively, it is true—that in comparison with conditions after a single-injection spinal anaesthesia—unfavourable changes occurred in Pa_{O_2} (d = −12.9 per cent), $A\text{–}aD_{O_2}$ (d = +9.5 mm Hg), $\dot{Q}s/\dot{Q}t$ (d = +66.7 per cent), pH_a (d = −0.42 per cent), HCO_3^- (d = −4.0 per cent) and B.E. (d = −1.45 mEq/l). Consequently these patients always need an extra supply of oxygen. If this is guaranteed, it is the author's impression that the unfavourable effects are overweighed by the subjective and objective advantages of this method. As is indicated by the results from section 2.5 this method –if well executed and supervised –offers advantages from a physiological viewpoint over other examined types of anaesthesia. The postoperative counteraction of pain is thus a logical continuation of the peroperative analgesia. The risk of extended spinal block in epidural block in old people (Mostert, 1964)[90] should not be forgotten, however.

Experiences from the investigation indicate that a body temperature deficit influences the postoperative bleeding and oxygen uptake. The method used in this study to estimate the body temperature is rough and involves errors (cf. Smith, 1962)[122], but it gave the impression that especially old and thin patients have considerable difficulties in normalizing their temperature spontaneously after operation. For this reason a postoperative routine control of body temperature and consideration of active rewarming are recommended in order to prevent increased endogenous heat production and consequently an increased oxygen uptake.

A significant carbon dioxide retention occurred after halothane anaesthesias with spontaneous ventilation. One patient had a brief circulatory collapse, probably on account of hypoventilation. The impression was obtained that the carbon dioxide retention after these anaesthesias was most pronounced in patients with reduced ventilatory capacity due to obstructive factors. On the other hand, a moderately reduced ventilatory capacity should not in itself be a contraindication for operations in old patients, as it has been shown that their postoperative ventilatory regulation does not differ in an unfavourable way from that in patients with essentially healthy lungs. The series investigated did not include any patients with major ventilatory impairment, however, and the conclusions therefore do not apply to such patients.

Very low Pa_{O_2} values were often observed postoperatively. It is a reasonable conclusion that an extra supply of oxygen must be given to all elderly patients and for a fairly long time in the postoperative period. Postoperatively, patients with progressively decreasing Pa_{O_2} due to an increased shunt effect should be treated with a respirator even at a state when Pa_{CO_2} is not elevated (cf. Holmdahl et al., 1966)[67]. On the basis of the results obtained, it may be said that neither fairly advanced age nor a limited reduction of the circulatory capacity should contraindicate anaesthesia and surgery. It should be pointed out, however, that no patients with an extremely low circulatory capacity were included in this investigation.

A circulation which on the average was hypokinetic as compared with that after other types of anaesthesia investigated, was indicated after anaesthesia with O_2-N_2O-d-Tubocurarine. The causes of this were not studied closely here. Hypothetically it may be ascribed to a negative inotropic effect of neostigmine or changes of the peripheral circulation. In elderly patients the circulation should always be extra carefully supervised in the postoperative period.

The acid-base balance in arterial blood was only negligibly changed, and a routine administration of alkalizing substances does not seem necessary.

The experiences of the anaesthesiologic care of patients during and after prostatectomy thus can be summed up as follows:

Spinal nerve block—without simultaneous general anaesthesia—appears to be advantageous from a physiological viewpoint. If the anaesthesia is administered as a continuous epidural block, good postoperative analgesia will be possible, which is easy to control. Hypoventilation due to high segmental levels of block must be avoided.

Neither moderately advanced age nor moderate reductions of the circulatory or ventilatory capacities should contraindicate anaesthesia and surgery.

In order to minimize the increase of oxygen uptake postoperatively, pain should be counteracted actively, the body temperature should be controlled and kept at a normal level and the per- and postoperative blood losses should be kept as low as possible and should be adequately replaced.

Chapter 5

SUMMARY

A group of 86 male patients, aged 60–86 years, were examined before and after transvesical prostatectomy. The group included patients with essentially normal heart and lung functions as well as patients in whom these were moderately impaired.

One examination involved the collection of samples of expired gas and both arterial and mixed venous blood, during periods of air and oxygen breathing. Examinations were performed preoperatively and 15 minutes and about 17 hours postoperatively. The patients were subgrouped at random to be treated by one of three types of anaesthesia: (H) Pentothal®-O_2-N_2O-halothane with spontaneous ventilation; (C) Pentothal®-O_2-N_2O-d-Tubocurarine with controlled ventilation; or (S) Spinal nerve block by means of either (Ss) subarachnoid anaesthesia or (Se) continuous epidural anaesthesia.

For the whole group a considerable average increase in the oxygen uptake was observed at the two postoperative examinations, while essentially adequate changes of the ventilatory minute volume occurred.

The arterial carbon dioxide tension diminished postoperatively in the oldest patients but not in the less old ones.

The preoperative values of ventilatory functional capacity or circulatory capacity did not predict the occurrence of postoperative changes in the respiratory function.

The type of anaesthesia used was of significance for the postoperative changes of respiration and circulation. Anaesthesia of type H was thus associated with a tendency to relative hypoventilation with acidosis, and type C with a tendency to relative hypokinetic circulation. To judge from the present study, and to generalize the findings for similar conditions, anaesthesia of type S should thus be preferred to types H and C if postoperative changes of respiration and circulation are to be minimized.

Even when followed by seemingly adequate replacement, greater blood losses during and after operation resulted in a greater increase of oxygen uptake and a more intensive oxygen extraction from arterial blood (i.e. a tendency to hypokinetic circulation) in the postoperative period than did small blood losses.

The practical clinical conclusions are that spinal nerve block, possibly extended by postoperative epidural anaesthesia, is recommended for operative procedures and patients of the types in the present study. Measures to prevent unnecessary increases of oxygen consumption, e.g. due to body cooling during the operation, are recommended during postoperative care.

ZUSAMMENFASSUNG

Untersucht wurde eine Gruppe von 86 Männern im Alter von 60–86 Jahren vor und nach transvesikaler Prostatektomie. Die Gruppe umfasst sowohl Patienten mit normalen wie auch mässig unphysiologischen Kreislauf- und Atmungsverhältnissen.

Der Untersuch umfasst die Bestimmung der Ausatmungs-, der arteriellen und gemischtvenösen Blutgase während Luft- und Sauerstoffatmung. Die Analysen wurden praeoperativ, sowie 15 Minuten und 17 Stunden postoperativ ausgeführt. Die Patienten erhielten zufälligerweise drei veschiedene Anaesthesitypen; (H-typ) Pentothal®-O_2-N_2O-Halothan in

Spontanatmung; (C-Typ) Pentothal®-O_2-N_2O-d-Tubocurarin mit kontrollierter Beatmung; (S-Typ) entweder Spinalanaesthesieblockade (Ss) oder kontinuerliche Epiduralanaesthesie (Se).

Beim gesammten Untersuchungsgut fiel in beiden postoperativen Messungen eine beachtliche Steigerung der Sauerstoffaufnahme auf, während eine entsprechende Steigerung des Atem- und Herzminutenvolumens auftrat.

Bei den ältesten Patienten sank postoperativ das arterielle P_{CO_2}, nicht aber bei den weniger älteren.

Die praeoperativen Werte der funktionellen Atmungs- oder Kreislaufkapazität praejudizierten keine postoperative Änderung vorbestehender Atmungsverhältnisse.

Von Bedeutung war die verwendete Anaesthesieart für die postoperativen Veränderungen der Atmungs- und Kreislaufverhältnisse. Während Narkosen vom H-Typ zu Hypoventilation mit Acidose neigten, zeigten die Narkosen vom C-Typ Tendenz zu hypokinetischer Zirkulation. Unter Voraussetzung gleicher Verhältnisse muss aus dem vorliegenden Untersuch Anaesthesien vom S-Typ der Vorzuggeben werden gegenüber H- und C-Typen, wenn die postoperativen Atmungs- und Kreislaufveränderungen minimal sein sollen.

Selbst bei scheinbar adaequaten Blutersatz, führten grössere per- und postoperative Blutverluste zu einer grösseren Sauerstoffaufnahme und intensiveren arteriellen Ausnützung (dh. Tendenz zu hypokinetischer Zirkulation) in der postoperativen Periode als Kleine.

Als Konklusion ergibt sich, dass die spinale Nervenblockade, möglicherweise erweitert durch postoperative Epiduralanaesthesie, für Patiententypen wie in diesem Untersuch, empfehlenswert ist. Massnahmen zur Verhütung unnötiger Steigerung des Sauerstoffverbrauches in der postoperativen Phase – zB wegen peroperativer Abkühlung – werden empfohlen.

Part II

Isometric muscle strength and physical working capacity after prostatectomy in relation to preoperative status and postoperative course.

Chapter 6

OUTLINE, MATERIAL AND METHODS

6.1 AIM OF THE INVESTIGATION

The aim of the investigation was to study the effect of the preoperative status, operation and postoperative course on some indices of physical capability in elderly patients. The indices chosen were isometric muscle strength and some reactions at a near-maximal physical exercise test.

6.2 MATERIAL

Of the 86 patients described in part I, 82 underwent exercise tests and 75 muscle strength measurements preoperatively.

Anthropometric data for the whole series have been given in part I. The physical working capacity at ex. I is given in Table 68. Static and dynamic spirometry was performed, according to conventional methods, with the patient supine in the ward bed. The results were expressed in per cent of the individually predicted normal value in the sitting body position[15, 18, 55], and the group average was found to be as follows. Vital capacity (VC): 84.6 per cent (SD 12.9); forced expiratory volume in one second ($FEV_{1.0}$): 77.5 per cent (SD 19.3); and the $FEV_{1.0}$/VC ratio: 87.8 per cent (SD 14.8).

Of the investigated series of 86 patients, the majority had had some diseases earlier in their lives which may have had a residual effect on their physical capabilities, among other factors, at the time of operation. Thus there were histories of pulmonary diseases as follows (see also Table 62, case 21): 12 cases of non-specific pneumonia, 1 spontaneous pneumothorax, 1 haemoptysis, 2 pleuritis, 1 operation for pleural empyema and 1 pulmonary tuberculosis. Noteworthy case history findings referring to the skeleton were as follows: 11 cases of fractures of vertebrae and/or the lower extremities, 1 traumatic below-knee amputation, 1 arthrodesis for arthrosis of knee, 1 severe arthrosis of hip and 6 rheumatoid arthritis. The frequency of previous abdominal operations was high: gastric resection in 6 cases, appendicectomy in 12 cases, laparotomy for intestinal perforation (other than the above) in 3 cases, repair of inguinal hernia in 12 cases and cholecystectomy in 10 cases. Some further cases are described in detail in Table 62.

At the postoperative follow-up examinations, not all patients could be examined (Table 60). Before ex. V, 2 patients had died (Table 61). A few other patients were excluded from this examination, either because they had no wish to take part (cases 6, 37, 39 and 64) or because it was considered that their condition did not allow examinations involving much exertion (cases 1, 11, 12, 25, 33, 35, 43 and 86).

Before ex. VI, a further 3 patients had died, 2 of whom had undergone bicycle ergometry and muscle strength measurements preoperatively (Table 61). Table 60 shows the number of patients who were followed up at ex. VI. A further 4 patients (cases 11, 50, 54 and 67) did not attend for the follow-up examination. One patient could not be examined completely because of cardiac decompensation (case 48) and another patient could not undergo bicycle ergometry because of joint symptoms (case 51).

6.3 POSTOPERATIVE MANAGEMENT

The treatment in the immediate postoperative period has been described in part I. Some parts of the further postoperative treatment are described below.

Drainage. Continuous bladder washout could generally be discontinued during the first day postoperatively. The suprapubic drainage tube was removed after 2.6 ± 2.2 days[1]) and the urethral catheter after 11.3 ± 10.3 days[1]).

Medicinal treatment. All patients were given epsilon-amino-caproic acid 5 g 4 times daily orally as long as the urine showed blood macroscopically. The majority of the patients were also treated with heparin (75 mg subcutaneously twice daily) during this period. starting on the morning of the first day postoperatively.

The examination in which intravascular catheters were used (see section 1.4), motivated antibiotic therapy (Ampicillin 0.5 g 4 times daily). This therapy was modified postoperatively according to the results of urine cultures and resistance determinations. The therapy was continued with sulfonamides or nitrofuradantoin even after the patient's discharge from hospital, for durations and in doses determined by the findings at follow-up examinations in the outpatient department.

Iron was administrated for at least two months from the 5th postoperative day onwards. Initially this was given intramuscularly in total doses of up to 1 g, after which the administration was oral.

With a few exceptions, all patients were given breathing exercises preoperatively and without exception postoperatively. They were mobilized as quickly as possible—in general they sat in a chair on the first day after the operation and walked on the second day. In a few cases, mobilization was delayed because of peroperative and postoperative complications.

6.4 COMPLICATIONS

Noteworthy cardiovascular and other complications are given in Table 63. These occurred in several cases relatively late in the postoperative course.

Malignancy. On histological examination of the prostatic specimens (at the Institute of Pathology, University of Upsala), unexpected adenocarcinoma was found in seven cases (cases 15, 32, 40, 43, 52, 64 and 76). One of these patients (case 32) died about six months postoperatively of extensive metastases from the carcinoma of the prostate. The other six patients were completely free from symptoms at the follow-up examinations, and there were no local signs or laboratory test indications of growth of the carcinoma. Five of the patients with malignancy were given hormone treatment (Estradurin®, Leo Ltd, Hälsingborg,

[1]) M ± SD

Sweden), while the other two were diagnosed as having carcinoma *in situ* and were only kept under supervision.

In one case (no. 74) a carcinomatous tumour of the bladder, the size of the end of a little finger, was excised at the time of the prostatectomy.

6.5 METHODS

The local surgical results were assessed by the same surgeon in all patients, on the basis of case history, residual urine volume, palpatory findings and any urinary tract infection.

The body weight (BW, kg) was determined on the wards, using conventional weighing scales.

Isometric muscle strength was measured by means of an apparatus consisting of a number of mechano-electric tranducers (Pressductor, ASEA Ltd, Västerås, Sweden) fixed on a testing chair in such a way that their position could be varied according to the size of the patient. The apparatus and the examination procedure have been described in detail by Bäcklund & Nordgren (1968)[10]. The apparatus was checked and calibrated regularly.

The following tests were performed (identification no. of test, and dimension, in brackets):

Muscles of the upper extremities:
Horizontal pull (1, kp)
Horizontal push (2, kp)
Muscles of the lower extremities:
Knee flexion (24, kpcm)
Knee extension (25, kpcm)
Muscles of the trunk:
Forward extension of the trunk (30, kp)
Backward extension of the trunk (31, kp)

The strength of the muscles of the upper and lower extremities was examined on both the right and left sides, the measurements being performed on one side at a time. Each test included three maximum strains with a duration of about 3 seconds each. The mean value of the two best results from each muscle group is given. As indicated above, the results of tests no. 1, 2, 30 and 31 are given in terms of force (kp), while 24 and 25 are given in terms of torque (kpcm), the force value in the latter cases being multiplied by the length of the tibia measured as by Tornwall (1963)[133]. All muscle strength measurements were performed by the author.

Muscle strength index (I_{musc}, per cent). This is given as the mean value for the force or torque in all muscle groups examined at ex. V and VI, each individual value being expressed in per cent of the result at the preoperative examination.

Total haemoglobin (THb, g). THb was determined by the alveolar CO method (Sjöstrand 1948[119], Wiklander 1956[140] and Linderholm & Söderström 1957[82]). With this method the patient breathes pure oxygen in a closed circuit system of known volume, and the fraction of carbon monoxide in this system is measured before and after the addition of a small, known volume of carbon monoxide. The procedures of examination and analysis were essentially the same as described by Wiklander (1956)[140] and Linderholm (1957)[79].

In a few cases THb was estimated from the plasma volume determined by the dye dilution method (Evans blue), and haemoglobin and haematocrit determinations.

Only single determinations of THb were performed on the different examination occasions. Only the results of those examinations at which the fraction of oxygen in the circuit system at the end of the examination was 90 per cent or more were included. Examinations with considerable "inward leakage" were thus excluded. The occurrence of "out-

ward leakage" could not be assessed. A special double mouthpiece was used to reduce the possibilities of leakage. In spite of this, several patients were unable to carry out this examination because of difficulty in preventing leakage.

Haemoglobin concentration (Hb, g/100 ml blood). Hb was determined spectrophotometrically. The method is described in section 1.5.

Total blood volume (TBV, l). TBV was calculated from the THb and Hb values obtained as described above.

In the few cases in which the plasma volume was determined by the dye dilution method (see above), TBV was calculated from this and the haematocrit values. Correction (0.90) was made for the ratio of the body haematocrit to the peripheral haematocrit value obtained from capillary blood (Gregersen & Rawson, 1959)[53].

Haematocrit (hct, per cent). See section 1.5.

Lactate concentration (lact, mEq/l). Two consecutive capillary blood samples were taken, commencing 15 seconds before the termination of the exercise test, for determination of the lactic acid concentration. The samples were analysed according to Ström's (1949)[128] modification of the Barker & Summerson spectrophotometric method. Duplicate determinations were made. The error of a single determination was 0.016 extinction units, which corresponds to about 0.18 mEq/l. The highest of the values from the two consecutive blood samples ($lact_{max.obs}$) served as the basis for the calculation of one of the indices expressing the physical working capacity (W_{lact}, see p. 67).

Electrocardiogram (ECG). ECG was recorded with a direct-writing apparatus (Mingograf 42 or Mingograf 81, Elema-Schönander Ltd., Stockholm, Sweden). With the patient at rest, in the recumbent position, recordings were made of the standard leads I, II and III, the unipolar extremity leads aVR, aVL and aVF and the precordial leads V_1, V_2, V_4, V_5 and V_7. After eight minutes of passive standing, the standard and precordial leads were recorded. Before the exercise test, the indifferent electrode for the precordial leads was moved to the forehead. Leads CH_2, CH_4, CH_5 and CH_7 were recorded both at rest and during exercise with the patient sitting up. Immediately after exercise, the standard and the precordial leads were recorded with the patient still sitting on the bicycle. The standard and precordial leads were also recorded in the recumbent position 4 min and 10 min after exercise. All ECG recordings were interpreted by the author.

Exercise test. Before commencement of the exercise test, the heart rate and auscultatory blood pressure were determined with the patient recumbent after 10 min rest and also after 8 min passive standing.

The exercise test was performed by means of an electrically braked bicycle ergometer (Holmgren & Mattsson 1954)[69], essentially in accordance with the principles given by Wahlund (1948)[137] and Sjöstrand (1951[120], see also review from 1960[121]). During the test, the ECG was monitored continuously on an oscilloscope, and CH leads were recorded after 5 min at each work load. The blood pressure was measured by auscultation during the fourth minute of each work load, and also the respiratory rate. The heart rate was determined after 2, 4 and 6 min at each load, by measuring the time for 25 cardiac cycles.

The initial work load was chosen according to the patient's history of physical capability, and was generally 200 or 300 kpm/min. After 6 min the load was increased by 100–300 kpm/min, according to the patient's subjective degree of effort, his subjective symptoms or the ECG reaction. At least two completed work loads were considered desirable, but this was not always possible. The exercise test was terminated when marked subjective symptoms occurred (e.g. musuclar fatigue, general fatigue, dyspnoea, local pain in the hip and/or leg, angina pectoris), when towards the end of a work load the heart rate (HR) increased to about 150, or on the occurrence of alarming pathological reactions (e.g. pathological ECG reaction, inverse blood pressure reaction, suspected signs of cerebral circulatory insufficiency).

The bicycle ergometers used for the exercise tests were calibrated regularly.

Physical working capacity (kpm/min). The physical working capacity is expressed as the

highest attained work intensity ($W_{max.perf}$)[1]), the calculated work load attained at HR 130 (W_{130}), and the calculated work load attained at a given lactate concentration in capillary blood (W_{lact}).

$W_{max.perf}$ is given as the work intensity at the termination of the exercise test. In cases where the exercise test was ended after a fully attained work load, $W_{max.perf}$ is given as this load. In the other cases, where the test was discontinued before 6 min had been completed at a particular work load, $W_{max.perf}$ is given, according to STRANDELL (1964)[124], as

$$W_{max.perf} = W_{n-1} + \frac{t}{6} (W_n - W_{n-1})$$

where W_{n-1} is the highest load attained during 6 min, and W_n the load immediately higher to W_{n-1}, which was discontinued after t min.

W_{130} was obtained by interpolation or extrapolation in the usual manner but without consideration of steady state conditions. Extrapolation was performed only when the final pulse at the last work load was not appreciably less than 130.

The relationship $W_{max.perf}$/log $lact_{max.obs}$ and HR/log $lact_{max.obs}$ were used in order to calculate, by inter- or extrapolation, the work load at an arbitrary blood lactate level (5 mEq/l), W_{lact}, the logarithmized value for the calculated lactate concentration at a heart rate of 130 (*log lact 130*) and the calculated heart rate at the arbitrary blood lactate level of 5 mEq/l ($HR_{log\ lact}$).

The highest observed lactate concentration in capillary blood ($lact_{max.obs}$, mEq/l) is given as the highest value of lactic acid concentration in capillary blood obtained at two consecutive samplings commenced 15 seconds before termination of the exercise test.

The 'heart rate—blood pressure' product (HR · $\overline{BP}$, units) is calculated to be roughly related to the left heart work within the individual as long as the stroke volume remains approximately constant. It is given as the product of the final heart rate (beats per second) measured at the highest work load and the final measured mean arterial blood pressure (mm Hg). The mean blood pressure was calculated as the diastolic blood pressure plus one third of the pulse amplitude.

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[1]) Nomenclature (cf. STRÖM, 1967)[129]: It was considered of clinical interest to give the highest attained work load, suitably in the form described by STRANDELL (1964)[124]. As an abbreviation, $W_{max.perf}$ is suggested. In the patients of the present study, the working capacity was often limited by extra-cardiopulmonary factors. In the other cases, the exercise tests were continued up to a variable proportion of the physical working capacity in different patients, although in the great majority to considerable tiredness, as judged clinically. $W_{max.perf}$ is thus based on an operational definition, and has no clear physiological meaning, although it probably—as an average—lies relatively near to the capacity and may have a significant clinical meaning.

Chapter 7

RESULTS

7.1 GENERAL RESULTS

The local surgical result was generally very good. Of those patients who were not followed up according to Table 1, one (case 11) had a moderate urethral stricture combined with slight incontinence. Another of the patients who were not followed up had non-specific symptoms with frequency of micturition. Among the patients who underwent follow-up examinations, strictures were noted in cases 1 and 18. These strictures were mild and could be treated at the outpatient department by means of probing at intervals of 1–3 months. No incontinence, significant volumes of residual urine or significant urinary tract infections were noted in the patients who were followed up.

Body weight (Table 64). This was decreased, on the average, by about 2 kg on discharge of the patients from hospital. At the follow-up examination 6 months postoperatively, the mean body weight was somewhat higher than preoperatively. The statistical significance of this change is shown in the table.

Isometric muscle strength (Table 65). The muscle strength in the arms (tests no. 1 and 2) decreased by 7–9 per cent during the period of hospitalization, but at ex. VI the mean values were significantly higher than preoperatively.

The muscle strength in the legs (tests no. 24 and 25) decreased by 6–16 per cent during the period of hospitalization. The increases at ex. VI were generally not significant.

The strength of the trunk muscles (tests no. 30 and 31) showed the greatest relative changes. At ex. V this had decreased by 18–29 per cent, but at ex. VI it was significantly higher than preoperatively.

The muscle strength index (Table 66), i.e. the mean, percentage change of the muscle strength in the different muscle groups in the individual patients, was decreased by 13 per cent at ex. V, and increased by 5 per cent at ex. VI. Both of these changes are highly significant.

Haemoglobin (Table 67). The haemoglobin concentration in capillary blood was, on the average, somewhat low, and showed large interindividual variations. At ex. V the mean value was decreased by 12 per cent, and at ex. VI it was somewhat increased compared with the preoperative value.

The total haemoglobin was, on the average, decreased by about 90 g at ex. V. The restitution at ex. VI was complete.

Physical working capacity (Table 68). W_{130} was not significantly changed at the postoperative examinations. Both the absolute and the relative values for W_{130} varied greatly on the different examination occasions.

$W_{max.perf}$ was reduced by 13 per cent at ex. V, but at ex. VI it was somewhat higher than preoperatively.

W_{lact} was changed in a similar way.

The 'heart rate—blood pressure' product (Table 69). At the highest work load in the bicycle ergometer tests, this product had decreased in essentially the same way as $W_{max.perf}$ and W_{lact} at ex. V. At ex. VI, however, the product was still somewhat lower than preoperatively.

The maximum observed lactate concentration in capillary blood immediately after exercise (Table 70) was somewhat higher postoperatively than preoperatively. The increase was significant at ex. VI.

Heart rate (Table 71). The *resting heart rate* (HR_{rest}) was, on the average, the same at ex. V as at ex. I. At ex. VI, however, the mean value was 5 per cent lower than preoperatively.

The *heart rate after eight minutes of passive standing* (HR_{ort}) was 5 per cent higher at ex. V than at ex. I; this difference is statistically significant. At ex. VI HR_{ort} was unchanged compared with the preoperative value.

The highest observed heart rate during exercise (HR_{work}) at the highest work load showed no significant differences on the different examination occasions. Expressed in per cent of HR_{rest}, HR_{work} had a value of 188 at ex. I, 185 at ex. V and 196 at ex. VI. The increases of the heart rate from the resting state were not statistically different on the different examination occasions.

The heart rate 10 minutes after exercise (HR_{aw}) was 4 per cent lower at ex. V and 5 per cent lower at ex. VI, compared with HR_{aw} at ex. I. The significances of these differences are given in Table 71.

Arterial blood pressures (Table 72). Both the *systolic* and the *diastolic arterial blood pressures in the recumbent position after 10 min rest* were highly significantly decreased at ex. V. The decreases were, on the average, 8 and 10 per cent, respectively. At ex. VI these blood pressures were unchanged compared with the preoperative values.

The *systolic* and *diastolic arterial blood pressures after 8 min passive standing* were highly significantly lower at ex. V than at ex. I. The mean decreases amounted to 14 and 15 per cent, respectively. At ex. VI these blood pressures were unchanged compared with the preoperative values. The changes in the systolic and diastolic blood pressures from the values after 10 min rest on the different examination occasions showed no statistical differences.

The systolic blood pressure at the highest work load was 16 per cent lower at ex. V than at ex. I. This difference is statistically highly significant. At ex. VI, BP_{work} was unchanged compared with the preoperative value. The blood pressure increase during exercise, from the resting value, amounted to 33.6 per cent at ex. I, to 29.6 per cent at ex. V and to 34,2 per cent at ex. VI. These changes show no statistical differences.

The systolic blood pressure 10 min after exercise was 10 per cent lower at ex. V than at ex. I, a difference which is statistically highly significant. At ex. VI, BP_{aw} was unchanged compared with the preoperative value. On the different examination occasions BP_{aw} was 2.8 per cent, 2.8 per cent and 4.2 per cent lower, respectively, than BP_{rest}.

ECG at rest, during orthostatic test and during and after exercise.

At ex. I, 17 (21 per cent) of the 82 patients were being treated with digitalis, at ex. V 15 (20 per cent) of 75 patients and at ex. VI 17 (24 per cent) of 72 patients. In 2 patients, digitalis therapy had been commenced after ex. V.

Abnormal ECG findings at rest, during orthostatic tests and also during and after exercise at ex. I, V and VI, are given in Table 73, together with the classification of these findings. Changes in rhythm at rest occurred equally often on the different examination occasions. Changes of the QRS complex were somewhat more common at the postoperative examination. This is explained by the occurrence of myocardial infarctions in cases 71 and 86. Changes in the ST-T region were somewhat less common at ex. V than at ex. I and VI.

Orthostatic ECG changes were most common at ex. V.

ECG changes during and after exercise occurred less often at ex. V than at ex. I, both changes in rhythm and in the ST-T region being of lower frequency than preoperatively. ST-T changes during and after exercise were most common at ex. VI.

Individual changes of ECG at rest and during and after exercise. On the average, the resting ECG was changed in an unfavourable direction at the postoperative examinations (Table 73). A regression of abnormalities, especially in the ST-T region, was observed, however, in several individual cases. The ECG pattern during and after exercise at ex. V thus was less pathological, or had even returned to normal, in a few cases. Interpretations of the unspecific ST-T changes at a work test are difficult to evaluate, and intraindividual changes are therefore not reported in detail here.

Subjective symptoms on termination of the exercise test (Table 74). A feeling of pronounced general exhaustion as the sole reason for termination of the exercise test was less frequent at ex. V than at ex. I. The average degree of exhaustion in these patients, without any noteworthy specific subjective symptoms, seemed to be somewhat higher at ex. V than at ex. I. In the table, patients who considered themselves able to manage a further and higher complete load were assigned to the group 'degree of exhaustion 1'; those who considered that they would have managed only a further few minutes, if the same work load had continued, were assigned to 'degree of exhaustion 2'; and those who considered themselves unable to carry on any longer were assigned to 'degree of exhaustion 3'.

Uncharacteristic pain, mainly in the hips and legs, occurred in the same frequency on the different examination occasions.

Muscle weakness and/or muscle fatigue in the legs were reported by a considerably larger number of patients at ex. V than at ex. I and VI. Assigned to this group were patients who completed a full load period but stated that they had a considerable sensation of fatigue from the leg muscles during the exercise test, or those who were unable to perform a full load period because of muscular weakness or fatigue even when the heart rate was only moderately increased.

Considerable breathlessness as a reason for termination of the exercise test was less frequent at ex. VI than at ex. I or V. Breathlessness was noted as being the predominant reason for discontinuation of the exercise test when, apart from a considerable subjective feeling of breathlessness, the patient also showed objective signs of pulmonary limitation of the physical working capacity (e.g. increasing cyanosis, abnormal changes in the respiratory rate, obstructive respiratory sounds).

Pain in the chest, substernal with a tendency to irradiation into arms or neck, with a character and a time course typical of or probable for angina pectoris, was less common postoperatively, with or without simultaneous ECG changes. Of the 5 patients who at the preoperative exercise test were judged to have angina pectoris, one was not examined at ex. V (fresh myocardial infarction), and another was not examined at ex. VI (cardiac decompensation).

Uncharacteristic cerebral symptoms as a reason for termination of the work test were noted in one patient at ex. V (increasing Parkinsonism) and in another patient at ex. VI (increasing headache after relatively recent concussion).

Paradoxical changes of blood pressure. A lower systolic blood pressure at the highest work load than at the immediately preceding load, as a reason for termination of the exercise test, was noted in 9 patients at ex. I, in 8 patients at ex. V and in 3 patients at ex. VI. In general this was not associated with any subjective symptoms.

7.2 RELATIONSHIP OF PREOPERATIVE STATUS AND PER- AND POSTOPERATIVE COURSE TO CHANGES OF MUSCLE STRENGTH AND PHYSICAL WORKING CAPACITY

Different groups of patients were selected from the series:

Evaluation of the importance of age. 21 patients who at the time of operation were older than 77 years and 6 months (A_{age}) were compared with 19 patients who at the time of operation were younger than 68 years and 6 months (B_{age}).

In the older age group, the relative value for the physical working capacity was lower at both postoperative examinations. Thus, giving M $\pm$ SEM in per cent of the initial value, W_{lact} in group A_{age} was 83.4 $\pm$ 4.2 at ex. V and 90.5 $\pm$ 4.6 at ex. VI, while in group B_{age} these values were 95.2 $\pm$ 3.8 and 107.1 $\pm$ 6.5. $Lact_{max.obs}$ was increased in group A_{age} at ex. V (113.9 $\pm$ 10.0

per cent), in contrast to group B_{age} (91.3 $\pm$ 5.0 per cent). Recent ECG abnormalities at rest and during exercise were noted only in group A_{age} at ex. V, while such abnormalities during and after exercise were most frequent in group B_{age} at ex. VI.

Evaluation of the importance of the preoperative ECG status. 23 patients who at the preoperative examination had shown an essentially normal ECG at rest and during and after exercise (A_{ecg}) were compared with 30 patients who in their resting ECG and/or ECG during and after exercise showed suspected pathological or pathological QRS and/or ST-T changes, interpreted as probable signs of coronary heart disease ($B_{ecg.chd}$), and 17 patients with a non-specifically pathological resting ECG or who during or after exercise exhibited an abnormal or suspected abnormal rhythm ($B_{ecg.p}$) which had not been noted at rest.

The changes of $W_{max.perf}$ in groups A_{ecg} and $B_{ecg.chd}$ at ex. VI were significantly different, thus $W_{max.perf}$ in group A_{ecg} increased to 107.6 $\pm$ 3.5 per cent, while in group $B_{ecg.p}$ it decreased to 95.9 $\pm$ 2.6 per cent of the initial value.

Evaluation of the importance of the preoperative physical working capacity. 28 patients with a preoperative physical working capacity (W_{lact}) of more than 500 kpm/min (A_w) were compared with 19 patients for whom this value was less than 400 kpm/min (B_w).

In these groups W_{lact} changed in different ways. At ex. V it was 84.1 $\pm$ 2.5 per cent in group A_w and 100.3 $\pm$ 4.2 per cent in group B_w. At ex. VI the corresponding values were 91.3 $\pm$ 4.2 per cent and 108.0 $\pm$ 6.3 per cent of the preoperative values, respectively. Two of the patients with a postoperative myocardial infarction were in group B_w.

Evaluation of the importance of the time of year of operation. 26 patients who underwent operation in the spring (February–June inclusive) were compared with 32 patients operated on in the autumn (September–December inclusive). At postoperative ex. V and VI, W_{lact} (expressed in per cent of the value at ex. I) was 9 and 15 per cent, respectively, higher in the spring group, and at ex. V $W_{max.perf}$ was 10 per cent higher in the spring group than in the autumn group. The differences between the groups are not significant, however.

Evaluation of the importance of the oxygen-transport situation of the patients in the early postoperative period. 19 patients with the best oxygen-transport situation at both ex. III and ex. IV (O_2uc 106 per cent or less of the value at ex. II, or—in those cases where O_2uc was not determined—Pa_{O_2} 100 per cent or more of the value at ex. II) were compared with 22 patients with the poorest oxygen transport situation at both ex. III and ex. IV (O_2uc 150 per cent or more of the value at ex. II, or—in those cases O_2uc was not determined—Pa_{O_2} 65 per cent or less of the value at ex. II). The groups were designated A_{ox} and B_{ox}, respectively.

The changes in total haemoglobin at ex. V were more pronounced in group B_{ox} than in group A_{ox} (80.6 $\pm$ 3.2 and 91.5 $\pm$ 2.8 in per cent of value at ex. I,

respectively). The changes in total blood volume were also different in the two groups (A_{ox} = 107.7 ± 3.5 per cent; B_{ox} = 92.2 ± 4.2 per cent). The muscle strength and physical working capacity showed similar changes in the two groups.

Evaluation of the importance of blood loss—adequately replaced. 29 patients with blood losses between ex. II and IV exceeding 1290 ml (A_{bl}) were compared with 30 patients with blood losses of less than 680 ml during a corresponding period of time (B_{bl}). In all patients the blood losses were adequately replaced.

The total haemoglobin and total blood volume were changed in different ways in the two groups at ex. V (THb: A_{bl} = 80.8 ± 2.7, B_{bl} = 91.8 ± 2.2; TBV: A_{bl} = 92.2 ± 3.8, B_{bl} = 105.0 ± 2.9 in per cent of values at ex. I). At ex. VI the haemoglobin concentration was most increased in group A_{bl} (A_{bl} = 107.0 ± 1.9 per cent, B_{bl} = 101.4 ± 1.7 per cent). Similarly the body weight on this examination occasion was most increased in group A_{bl} (A_{bl} = 103.2 ± 0.9 per cent, B_{bl} = 100.1 ± 0.9 per cent).

Evaluation of the importance of the duration of the postoperative catheter drainage. 21 patients in whom the endourethral catheter was not removed finally until the 14th postoperative day or later (A_{cath}) were compared with 24 patients in whom the catheter was removed finally on or before the fifth postoperative day (B_{cath}).

The groups differed at ex. V with regard to changes in the total haemoglobin (A_{cath} = 83.4 ± 2.2, B_{cath} = 90.9 ± 2.7 in per cent of value at ex. I) and in $W_{max.perf}$ (A_{cath} = 80.0 ± 5.5 per cent, B_{cath} = 93.3 ± 3.7 per cent).

The results of these comparisons are summarized in Table 75. The time of year of the operation was found to have no significant influence on the changes of the parameters studied, and is not included in the table.

Chapter 8

DISCUSSION

8.1 EVALUATION AND VALIDITY OF THE RESULTS

The occurrence of complications meant that some patients were not investigated postoperatively. The number of patients thus excluded can be seen in Table 60. These exclusions complicate evaluations of the postoperative changes, as also do the possible effects of variations in the degree of co-operation and repetition of the examinations. The group of exclusions, which included patients with considerable functional limitations, can involve a systematic error. Variations in the degree of co-operation and the familiarizing and training effects of repeated examinations, on the other hand, probably have no systematic significance.

Co-operation at the examination. The degree of co-operation appeared to be excellent in practically all cases, and from this aspect the values obtained should well reflect the state of patients on the different examination occasions. In a few isolated cases the patients stated at ex. V that they did not wish to exert themselves excessively, and the strain on their circulatory and respiratory systems was possibly lower on that occasion than otherwise. Also, in view of the nature of this series of patients, the tests were not driven harder than to that limit allowed by the patients themselves or by the clinical judgement of the author. In spite of this, the "limitation criteria" remained unchanged. The average degree of exhaustion during the exercise tests, and also $lact_{max.obs}$, were essentially unchanged postoperatively compared with preoperatively. The results obtained are therefore considered to reflect the average individual course of the physical capability with the form and type of exercise used on the different examination occasions.

Influence of pain. One possible weakness in the foregoing reasoning might be the influence of pain on the heart rate during exercise at ex. V. No such influence was evident clinically, however. For example, pain in the wound area did not limit the achievements of the patients in the exercise tests. Uncertain limiting *pains in the joints* occurred in a few cases—predominantly preoperatively. *Muscular pains*—after repeated intramuscular injections before the exercise test—occurred at ex. V but were not of a limiting extent. Thus, subjectively, pain factors do not appear to have contributed noteworthily to the changes in physical working capacity.

For the measurements of the strength in the trunk muscles, pain in the wound area was of some importance. At ex. V a few patients refused this examination, and a few stated that pain in the wound limited their achievements. The majority of patients, however, stated that they were completely free from pain at this examination. Articulo-muscular pains in patients with diseases of the joints or post-traumatic conditions were most pronounced preoperatively, but were not, with certainty, of a limiting extent, and neither were pains in the thigh muscles, which occurred postoperatively after injections.

Effects of repeated examinations. Repetition of bicycle ergometry, with the intervals used here, in elderly persons with no cardiac disease does not influence the results of the examina-

tions by an effect of training or familiarization with the procedure (Strandell 1964)[125]. A psychological effect of the whole procedure, which indirectly stimulated the patients to increased physical training or activity in their daily life, cannot be excluded, however, although this was not evident from their case histories. In examinations of patients with coronary insufficiency, good reproducibility of the results has been found (Hallén, 1964)[57]. Repeated tests of muscle strength give essentially similar values with good precision (Bonde Petersen, 1959)[21], with the exception of the strength in the trunk muscles (Tornvall, 1963)[133].

The magnitude and direction of the average changes are influenced by the manner in which the individual changes are calculated. These can thus be given as absolute values or relative values from a reference level which has either been measured or calculated. In these cases the mean individual changes will be different. Statistical problems of this kind are discussed by Adolfsson (1969)[1]. In the present investigation the changes are expressed in per cent of the values obtained at the preoperative examination. These relative values are complemented in the tables by absolute values from the different examinations.

8.2 ISOMETRIC MUSCLE STRENGTH

Results from measurements of isometric muscle strength by the method used here have been published previously only by Bäcklund & Nordgren (1968)[10]. These authors compared their results with those of Asmussen & Nielsen (1961)[7] and found lower values for horizontal pull, knee flexion and backward extension of the trunk, essentially similar values for horizontal push and forward flexion of the trunk and essentially higher values for knee extension. The discrepancies can probably be explained partly by differences between the two series investigated, but also (knee extension) by differences between the methods used.

The highest values achieved by the individual patients on any of the examination occasions have been used for presentation in Table 76 of isometric muscle strength in higher age groups. Patients with limiting cardiopulmonary diseases have been excluded here, as also have the results from examinations of the dorsal muscles in patients with back symptoms and those from examinations of extremities with previous considerable traumatic damage or diseases of the joints. For various reasons, this series cannot be regarded as representative of a normal population of this age.

The muscle strength can be well retained in fairly high age groups (Fig. 32). The occurrence of a surgical disease, such as prostatic hyperplasia, probably results, however, in reduction of the muscle strength (Table 77), e.g. from immobilization or infections, but this does not appear to have been analysed closely in the literature.

On the average, reductions of muscle strength at ex. V were noted. These were most pronounced in the quadriceps muscle (about 15 per cent) and in the muscles of the trunk (20–30 per cent), and can be partly explained by

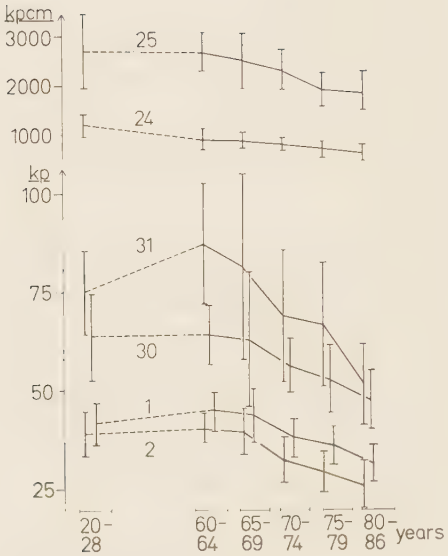

FIG. 32.—Isometric muscle strength (M ± SD, force in kp, torque in kpcm) in some large muscle groups (test nos. as indicated on p. 65) in younger (20–28 years, BÄCKLUND & NORDGREN, 1968[10]) and in elderly males (60–86 years, RENCK, present series). See text for further explanation.

inhibition due to pain. Measurements of the muscle strength in the trunk are, on the other hand, relatively unprecise owing to the difficulties of the patients in co-operating optimally, which may mean that the decreases reported may be falsely small. At ex. VI the muscle strength index was, on the average, somewhat higher than preoperatively (5.4 per cent), and in all muscle groups tested increases in strength were noted. For the muscles of the legs, however, these were not significant. The preoperative status and postoperative course were not found to be of any importance for the changes in muscle strength.

What were the consequences of the changes in muscle strength for these patients?

Subjective symptoms in the form of muscle fatigue and/or weakness in the legs occurred in an increased frequency at the exercise tests at ex. V.

The patients in whom subjective symptoms from the legs occurred during the exercise test at ex. V but not at ex. I did not, on the average, show greater decreases in the strength of the quadriceps muscles than the patients of the whole series.

The fact that many patients felt unsteady and had weakness of the legs postoperatively may have been due, however, not only to muscle weakness but also to altered circulatory conditions. Postoperative changes in the circulatory conditions and their consequences for the muscular blood flow are discussed below.

Only one patient was troubled by more pronounced muscle weakness postoperatively (case 71, see section 6.2). In this case the postoperative course was extremely complicated and prolonged. With active physical training the muscle strength in the legs was subsequently restored to a level acceptable to the patient.

The increase in muscle strength at ex. VI indicate that an increase in activation may result in greater muscle strength even in older persons, thus, in principle a 'training' effect as in young persons but with quantitative differences. In general, the muscle strength of older persons probably lies at a lower initial level than that of younger persons, and thereby reacts to even mild exercise (cf. Bonde Petersen, 1959)[21].

If, thus, the increases in muscle strength at ex. VI can probably be largely ascribed to effects of increased physical activity, the reasons for the decreases in the early postoperative course are not equally clear. In many cases there would seem to be an effect of immobilization. For patients with a low preoperative habitual physical activity, however, the relative degree of immobilization postoperatively would probably not be so high as for patients in whom the preoperative physical activity was high. It is therefore surprising that the patients with the highest preoperative physical working capacity showed the same relative decreases in muscular strength index as those with the lowest physical working capacity preoperatively.

8.3 PHYSICAL WORKING CAPACITY

By physical working capacity is meant here the capacity for external work during a long period of time, with high intensity and the involvement of large muscle groups. This is dependent, in principle, upon the capacity, regulation and homeostasis of the oxygen transport, and therefore mainly upon the circulatory and to some extent the respiratory functional capacity. The physical working capacity is often expressed indirectly as the calculated work load at a given heart rate or (in healthy persons) as $\dot{V}_{O_2max}$. These indices are valid only if it is taken into account that HR_{max} decreases with increasing age (at 20 years about 200, at 70 years about 150) and also that the capacity for a steady state is an important aspect of the physical working capacity which is not expressed in the two indices. For younger persons a heart rate of 170 is generally used, while for older persons lower heart rates are usually preferred (150 or 130, cf. Strandell, 1964)[124]. Also the maximal physical working intensity (W_{max}) is used in different forms to express the physical working capacity, but then it must be stated which "criteria for maximum" or "limitation criteria" are used.

W_{130} was probably not a satisfactory parameter for expressing the physical working capacity and its changes in this investigation. This is not in agreement with the experiences of Strandell (1964) [124, 126] from studies of healthy old men. The fact that W_{130} varied within wide limits and showed paradoxical changes (Table 68) may be due to different factors:

a) HR_{max} probably varied between different individuals of the series. Thus, preoperatively $HR_{max.obs}$ varied between 96 and 175 with no definite relationship to $lact_{max.obs}$ or to the subjective degree of exhaustion. Extrapolation or interpolation of W_{130} in these cases probably expressed completely different proportions of the physical working capacity of the patients. When the extrapolation was limited to a reasonable extent, W_{130} could only be given for 55 out of 75 patients in this series at ex. V.

b) It is probable that HR_{max} also varied intraindividually in the series. $HR_{max.obs}$ showed in some cases large intraindividual variations between the different examination occasions at essentially similar work loads, subjective degrees of exhaustion and $lact_{max.obs}$ (e.g. case 74 = ex. I:175, ex. V:116, ex. VI:180; case 82 = ex. I: 122, ex. V: 175, ex. VI: 133). The changes of W_{130} thus become difficult to interpret.

$W_{max.perf}$ is a parameter subject to other weaknesses. During the three years of the investigations, the exercise tests could not be carried out in an identical manner. Thus for different patients the preoperative exercise tests may to some extent have been randomly carried out to somewhat varying degrees of exertion. Furthermore, the work loads chosen differed to some extent, depending on the patient's present history of physical capability. Also, intraindividual variations of the work loads at the exercise tests occurred to some extent, dictated by variations in the heart rate reaction and subjective symptoms at the examinations. $W_{max.perf}$ does not therefore always express the same proportion of the maximal physical working capacity even within the same individual. Individual changes may be due partly to effects of extracardiopulmonary factors.

W_{lact} expresses the calculated work load at a certain blood lactate concentration, i.e. a certain degree of anaerobic metabolism, assuming an unchanged muscular glycogen store. The influence of interindividual and/or intraindividual variations of HR_{max} are thereby reduced, as also are the effects of extra-cardiopulmonary factors. According to STRANDELL (1964)[127], log lact concentration during exercise is significantly related to heart rate. This index can, however, be affected by metabolic factors (AHLBORG, 1967)[2], especially in the form of the preceding food intake and the preceding degree and duration of muscular effort. These factors influence, among other things, the glycogen depots in the skeletal muscles, which are an important source of lactate formation. STRANDELL (1964)[127] states, further, that it is the anaerobic metabolism in the working muscles that should be the main limiting factor for the working capacity in bicycle ergometry in healthy old men. In the series presented here, log lact 130 was probably significantly increased at the postoperative examinations while $HR_{log\ lact}$ was negligibly decreased (Table 70). In combination with the variations of $HR_{max.obs}$ described above, this indicates the justification of using the lactate-related work load as the main expression of the submaximal working capacity. It is reasonable to assume that W_{lact} is dependent upon both the capacity of the oxygen transport of the cardiovascular system and the adaptability of the peripheral circulation.

Some of the difficulties, including variations in mechanical efficiency, in expressing the physical working capacity in an acceptable way could have been avoided if the oxygen uptake had been determined during the exercise tests. This was not considered practicable in this series of patients, however.

This introductory discussion can be summarized by saying that at present there are no expressions for physical working capacity and its changes in a series such as that described here that are completely free from criticism, well investigated and practically applicable. Even though the expressions used here have been considered to be acceptable, further investigations of the methodological aspect would seem to be important.

The physical working capacity, judged from W_{lact} and $W_{max.perf}$, was decreased at ex. V. The age of the patients is probably of importance in this

respect (see p. 71), and also their preoperative physical working capacity (see p. 72). The degree of severity of the postoperative course—expressed as the duration of the catheter drainage –is also probably of importance (see p. 73).

At ex. VI, the physical working capacity was higher, on the average, than preoperatively. For the changes at this examination, the preoperative state of the patients was probably of some importance. Thus there appears to be influence by age (see p. 71), preoperative physical working capacity (see p. 72), and ECG status (see p. 72).

How can the changes in physical working capacity at ex. V be explained?

Haemoglobin conditions. Normally there is a relationship between physical working capacity and the haemoglobin conditions even in elderly persons (Strandell, 1964)[126]. In younger persons, an acute reduction of the red cell volume results in a transient decrease of the physical working capacity (Gullbring et al., 1960)[56] until the blood volume is restored by an increase in the plasma volume. In the present series both the total haemoglobin and the haemoglobin concentration were decreased at ex. V, despite an essentially adequate replacement of blood loss (cf. Norlander et al., 1954)[94]. The validity of the changes of the total haemoglobin reported for the present series is, from a methodological aspect, open to discussion, but the unchanged ratio W_{lact}/THb at ex. V (Table 78) indicates that the decrease in haemoglobin was of importance for the reduction of the physical working capacity. No distinct relationship between individual changes of W_{lact} and THb was found, on the other hand.

Myocardial factors. The appearance of new ECG changes during the observation period, indicating myocardial disorders, could not be related to changes in the physical working capacity. At ex. V it was found that in several cases ECG changes noted preoperatively—especially within the ST-T region— had decreased. Neither could this reduction of ECG changes be related to changes in the physical working capacity. Of interest in this connection is the fact that out of the five patients who at the preoperative exercise test had subjective symptoms interpreted as angina pectoris, only one of the four followed-up reported symptoms at ex. V. A lower physical working intensity ($W_{max.perf}$) and/or, 'heart rate ·blood pressure' product (under certain conditions a relative measure of the work of the heart) can possibly explain why angina pectoris did not occur postoperatively.

No distinct relationship between changes of the 'heart rate—blood pressure' product and of the physical working capacity was observed.

To summarize, no evidence was found to indicate that changes of the physical working capacity could be mainly dependent upon cardiac functional factors.

Peripheral circulation. The mean blood pressure level at rest and during exercise was decreased at ex. V. Theoretically (Poiseuille's law) a lower arterial blood pressure during exercise means that a relatively smaller proportion of the cardiac output can be distributed to the working muscles by means of

local changes in peripheral resistance. This applies particularly in cases where the blood vessels of the muscles are affected by arteriosclerotic changes. At ex. V, $W_{max.perf}$ was decreased but $lact_{max.obs}$ and log lact 130 were increased. This may indicate a reduced relative adaptability of the peripheral circulation. The increased occurrence of subjective symptoms from the legs during the exercise test at ex. V may also be due partly to locally altered circulatory conditions (cf. p. 76).

The reasons for the blood pressure reduction can only be discussed hypothetically. The blood pressure is determined normally by the cardiac output and its distribution in the blood vessels, the peripheral resistance and, partly, the viscosity of the blood. None of these factors were studied. TBV showed no change, however, and the viscosity was probably somewhat decreased (reduced haematocrit value) at ex. V. An increased vagal tonus at rest and a decreased sympathetic tonus during exercise could possibly have contributed to the regression of the ST–T changes of the EGC but this is partly contradicted by the unchanged resting pulse.

Immobilization is followed by decreases in physical working capacity (Deitrick et al., 1948[35], Rodahl et al., 1966[105]). The decreases are most pronounced in persons with a high degree of physical fitness (Blomquist et al., 1968)[19]. In the present series the degree of severity of the postoperative course varied, and thereby also the duration and extent of immobilization. For this reason some patients could not be examined at ex. V. No distinct relationship was found between changes in physical working capacity and the degree of severity of the postoperative course, although the duration of the postoperative catheter drainage was probably of some importance. This lack of relationship may be an expression of the averagely low preoperative degree of physical fitness of these patients. For many of them, the postoperative period did not mean any essentially greater degree of immobilization, compared with preoperatively. An increased metabolism in the immediate postoperative period (cf. section 2.1) and early and active mobilization possibly meant for some patients an increase in circulatory effort. For other patients, who were physically very active before the operation, the postoperative course may have meant, on the other hand, relative immobilization. The changes in physical working capacity in the groups with a high and low preoperative physical working capacity, respectively, support this possibility (see p. 72).

What factors may conceivably be of practical importance for the restoration of the physical working capacity in elderly patients in the late postoperative course?

Haemoglobin conditions. The total haemoglobin and the haemoglobin concentration were restored at the examination six months after the operation. Neither was any distinct relationship noted between individual changes in total haemoglobin and physical working capacity at this examination.

Myocardial factors. No relationship between individual changes in the 'heart rate –blood pressure' product and physical working capacity was observed.

Neither the occurrence nor the regression of ECG changes was found to have any noteworthy influence on the changes of physical working capacity.

The series of patients followed up at ex. VI included two patients who had had myocardial infarctions postoperatively. In one of them (case 86), considerable subjective and objective improvement of the physical working capacity were noted (W_{lact} increased by 32 per cent), while in the other patient there was a corresponding deterioriation (W_{lact} decreased by 31 per cent). In this latter patient (case 71) the course following the infarction was very complicated (see Table 63), but subsequent physical training resulted in a subjectively satisfactory restoration.

Peripheral circulation. The arterial resting blood pressures and their relative changes during the different parts of the exercise test did not differ at ex. VI from the preoperative conditions. No close studies of the peripheral circulation were made.

Ambulation and physical training. The case histories of the patients indicated, in general, an increased degree of physical fitness at ex. VI. Several patients, whose physical activity was limited preoperatively by their disease, were able to increase this activity considerably after the operation. Other patients, on the other hand, whose degree of physical activity preoperatively was relatively high, had not regained this at ex. VI. There are several reasons for this postoperative variation of the relative degree of physical fitness, and they are probably connected, among other things, with varying motivation for physical activity and the occurrence of intercurrent diseases (e.g. case 60: gallstone disease and cholecystectomy, case 65: intra-abdominal malignancy, case 79: concussion). It is probable that in no case did the surgical result have a negative influence. The younger patients, who—it is reasonable to assume –had greater reason to return to a higher relative level of activity than the older patients, exhibited a higher relative physical working capacity at ex. VI (see p. 71). The patients with no ECG indications of coronary disease should have had greater physical prerequisites for maintaining a higher relative degree of physical fitness postoperatively than the patients with coronary heart disease. The changes in physical working capacity in the ECG groups support this assumption (see p. 72). The patients with a low preoperative physical working capacity increased this at ex. VI, in contrast to those with a high preoperative working capacity (see p. 72). This may be due, among other things, to the fact that the patients with a low physical working capacity preoperatively were immobilized more by their surgical disease than those with a high preoperative physical working capacity.

In the early postoperative stage the patients were encouraged to active mobilization, as is the current procedure in this clinic. Even while still in hospital, all patients were advised to increase their activity successively, to an extent modified by individual factors. No dose control of the physical training of the patients was made. It is conceivable that the summer season can mean a greater stimulus to physical activity than the winter. The patients who were

operated on in the spring had a tendency to increase their physical working capacity at ex. VI (W_{lact} had increased by 9.7 $\pm$ 7.4 per cent), in contrast to those operated on in the autumn (W_{lact} had decreased by 5.0 $\pm$ 3.7 per cent). The difference is not significant, however.

The physical activity of the patients after the operation thus seems to be essential for restoration of the physical working capacity. A good surgical result gives prerequisites for relative increases in the physical activity and the physical working capacity. In this series the surgical result was good, and therefore possible unfavourable effects of an unsatisfactory surgical result cannot be assessed.

Of the 18 patients whose per- and postoperative courses were complicated, mainly from a surgical aspect, three had died before ex. VI and a further two could not be examined on that occasion. In the 13 patients who were followed up, the physical working capacity was restored satisfactorily (W_{lact} = 97.7 $\pm$ 5.5 per cent of initial value). No distinct relationship between the degree of severity of the complications and the changes in physical working capacity was found.

Chapter 9

CLINICAL IMPLICATIONS

The good surgical results and the average improvement in the physical capabilities in the present series of patients support the justification of elective prostatic surgery in elderly patients. This probably holds also for several other forms of elective surgery in the elderly. Geriatric surgery is associated with an increased frequency of complications, on the other hand. For this reason some authors have advised against too wide indications in such procedures (cf. 'General introduction'). However, there seems to be no evidence from the present study that the indications for elective prostatic surgery should be especially narrow in elderly patients.

The following discussion is limited to general aspects of the preparation of elderly patients for operation, and the postoperative management.

PREPARATION FOR OPERATION

Reduction of the degree of physical fitness by the surgical disease has been discussed previously. In order that the patients should be in an optimal physical condition at the time of operation, surgical measures should be taken within a reasonable time after the manifestation of the disease. If this is not possible, the physical capability of the patient can probably be increased—and thereby perhaps the operative risk decreased—by well controlled, preoperative physical training. In order to increase the oxygen-transporting capacity, the total haemoglobin should be normalized preoperatively. Care should be taken that the patient has an adequate caloric intake and an adequate supply of erythropoietic factors in good time before the operation. Only in exceptional cases should transfusions of erythrocyte concentrates be considered (cf. Holmdahl et al., 1966)[67].

AVOIDANCE OF PER- AND POSTOPERATIVE COMPLICATIONS

A careful preoperative survey of the vital functions of the patient can, by serving as a basis for individualization of the pre-, per- and postoperative treatment, reduce the risk of complications. When the functional capacity of the patient is known, an experienced and observant staff can take necessary

measures against threatening complications at an earlier stage than would otherwise be possible.

Minor blood losses and a short period of immobilization produce only negligible effects on the circulation in the immediately postoperative period (see section 2.6) and on the physical working capacity two weeks postoperatively, respectively. When possible, the type of surgical operation chosen should be such that early mobilization can take place.

In this connection, it would seem desirable for studies to be made of the effects of minor, almost palliative surgical operations on the physical capabilities and local function. In the patients of the present investigation a relatively large operation gave a very good local result but probably sometimes also a prolonged reduction of the physical capabilities. A convalescence period of, for example, four months, means for an eighty-year-old about 7 per cent of the expected 'natural' survival time, but for a thirty-year-old only about 0.6 per cent.

Preventive measures against infection, thrombosis and embolism should be taken routinely.

Cardiovascular complications were in this series most frequent in the second and third postoperative weeks and in two cases they occurred immediately after discharge of the patients from hospital (cases 48 and 71). The physical activity of the patients should be increased successively after the operation in order to reduce the risk of complications (cf. cases 12, 48 and 71). Careful instructions to the patients and staff, and ambulation preferably supervised by the doctor and/or physiotherapist should do much to diminish this risk. Routine, postoperative ECG examinations can reveal clinically occult complications (cf. cases 71 and 86) which then can be treated adequately. A satisfactory physical restoration can be expected in many cases even after initially fairly serious cardiovascular complications.

The hospital mortality in this series was 2.3 per cent (2 out of 86 patients). No close comparison can be made with other series because of the principles followed for selection and treatment. Provided that measures such as those outlined in this section and in part I are taken, it should be possible to keep the mortality in connection with prostatectomy at such a low level that it cannot be used as an argument against elective prostatic surgery even at advanced ages. This applies to healthy elderly persons and elderly persons with moderate reductions of the ventilatory and circulatory functional capacities. Patients with a reduced renal function or with pronounced reductions of the circulatory and/or ventilatory functional capacities, and those with marked mental disorders cannot be discussed on the basis of this study. Good local results and appreciative patients with averagely increased physical capabilities make this form of surgery satisfying and important. Conducted in the ideal manner, however, such treatment is costly and time-consuming.

Chapter 10

SUMMARY

Isometric muscle strength and physical working capacity were studied before and at different times after transvesical prostatectomy.

The muscle strength in some large muscle groups was decreased below the preoperative level by an average of 13 per cent two weeks postoperatively, and six months later was instead increased by an average of 5 per cent above the preoperative level. The preoperative state of these patients and their postoperative course were found to have no influence on the changes in muscle strength.

Different expressions for physical working capacity are discussed. A parameter, in which the working capacity is related to the lactate concentration in capillary blood, is presented. Two weeks postoperatively the physical working capacity was decreased by 10 per cent, but after six months it had regained the preoperative level. The oldest patients in the series showed the greatest mean decrease in physical working capacity 14 days postoperatively, and—in contrast to those who were slightly younger—had not restored their physical working capacity on examination six months postoperatively. The patients with ECG indications of coronary heart disease had not restored their working capacity six months postoperatively, in contrast to those with an essentially normal ECG. The patients with the preoperatively lowest working capacity showed no decrease in this value on examination 14 days postoperatively, and on examination six months postoperatively it had increased, all in contrast to the conditions in patients with the highest working capacity preoperatively.

In the postoperative course neither the oxygen transport situation, the magnitude of the adequately replaced blood loss nor the postoperative temperature reaction appeared to have any influence on the changes in physical working capacity. The duration of the postoperative catheter drainage was probably of importance, however, for these changes.

In the section on clinical implications the pre- and postoperative treatment of elderly patients is discussed. Physical training of the elderly both pre- and postoperatively is advised. Preoperative normalization of the haemoglobin conditions is recommended, as well as adequate substitution of per- and postoperative blood losses. The risk of postoperative cardiovascular complications is pointed out. Routine postoperative ECG examinations are recommended, and also early, active and very carefully controlled postoperative ambulation and training of patients of this category.

ZUSAMMENFASSUNG

Es wurde die isometrische Muskelkraft und körperliche Leistungsfähigkeit vor und zu verschiedenen Zeiten nach transvesikaler Prostatektomie untersucht.

Die Muskelkraft in einigen grossen Muskelgruppen war im Durchschnitt zwei Wochen postoperativ um 13% vermindert und lag 6 Monate später durchschnittlich 5% über dem praeoperativen Wert. Der praeoperative Zustand dieser Patienten und der postoperative Verlauf haben in diesem Zusammenhang keinen Einfluss auf die Veränderung der Muskelkraft.

Es wurde verschiedene Formen der körperlichen Leistungsfähigkeit diskutiert. Es wurde eine Relation gefunden bei welcher die Leistungsfähigkeit im Zusammenhang mit der Laktatkonzentration des Kapillarblutes steht.

Zwei Wochen postoperativ war die körperliche Leistungsfähigkeit um 10% erniedrigt, erreichte aber nach zirka 6 Monaten die praeoperativen Werte. Die ältesten Patienten der Serie zeigten 14 Tage postoperativ durchschnittlich die grösste Leistungsverminderung. Im Gegensatz zu den weniger Aelteren hatten sie bei Untersuchungen 6 Monate postoperativ ihre körperliche Leistungsfähigkeit wiedergewonnen. Patienten mit Zeichen von Koronarerkrankungen im EKG, haben im Gegensatz zu solchen ohne diese Zeichen ihre körperliche Leistungsfähigkeit 6 Monate postoperativ nicht wieder erreicht. Patienten mit der praeoperativ geringsten Leistungsfähigkeit, zeigten 14 Tage postoperativ keine Verminderung und beim Untersuch 6 Monate nach der Operation sogar eine Zunahme derselben, ganz im Gegensatz zu den Patienten mit der höchsten praeoperativen Leistungsfähigkeit. Für die Veränderungen in der körperlichen Leistungsfähigkeit schienen weder die unmittelbar postoperativen Sauerstofftransportbedingungen, noch die Grösse des adaequat ersetzten Blutverlustes, noch die postoperative Temperaturerhöhung, verantwortlich zu sein. Die Dauer der postoperativen Katheterdrainage war möglicherweise von Bedeutung für diese Unterschiede.

Im Abschnitt: "Klinische Folgerungen" wurde die prae- und postoperative Behandlung der älteren Patienten diskutiert. Körperliches Training des Aelteren Patienten sowohl praewie postoperativ, ist angezeigt. Die praeoperative Korrektur der Haemoglobinkonzentration wie auch adaequater per- und postoperativer Ersatz des Haemoglobinverlustes wird empfohlen, auf das Risiko postoperativer kardiovaskulärer Komplikationen wurde hingewiesen. Routinemässige postoperative EKG Untersuchungen, sowie frühe und sorgfältig kontrollierte Mobilisation und Training dieser Patientengruppe ist angezeigt.

ACKNOWLEDGEMENTS

This study was carried out at the Departments of Anaesthesiology, Clinical Physiology and General Surgery at the University Hospital in Upsala. I would like to convey my sincere thanks to the chiefs of these three departments for their advice and positive criticism. My grateful thanks are also due to Dr. Anders Engberg who operated on most of the patients in the study, and whose genuine interest in the problems concerned was of great help.

A great number of persons were involved in this investigation. Hoping that nobody will feel left out, I wish especially to thank the nurses Ulla Eriksson, Solweig Larsson and Lilly Axelsson, who assisted at the examinations of the patients in an exemplary manner, the doctors and staff of the surgical wards, the central operating theatre, the intensive care unit, the surgical outpatient department, the department of clinical physiology, and the department of diagnostic radiology, and the secretaries at the department of anaesthesia, who in spite of their great burden of routine work contributed in an often unselfish way towards this investigation.

Financial support was generously given by the University of Upsala, the Swedish National Association for Heart and Chest Diseases, the Swedish Medical Research Council (projects No K68–14x–2127–02, B67–17x–2127–01, B67–61P–2098–01), Axel Linder's foundation and Victor and Albertina Molinder's foundation.

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TABLES

TABLE 1.
Investigation programme.

Day	Investigation	Ex.no
	Visit to the patient's home, examination of the patient and interview of the patient, a relative or nurse	I
1	Admission to hospital	
	ECG	
	Physical examination	
2	BMR	
	Urethrocystoscopy	
4	Estimation of total haemoglobin	
	Psychometric tests*	
	Bicycle ergometry	
5	Measurement of isometric muscle strength	
	Roentgenological estimation of heart volume*	
	Psychiatric examination*	
	Psychometric tests*	
	EEG**	
6	Lung X-ray	
	Respiratory and circulatory examinations (Table 4)	II
	Operation	OP.
	Respiratory and circulatory examinations (Table 4)	III
7	Respiratory and circulatory examinations (Table 4)	IV
18	Psychiatric examination*	V
	Psychometric tests*	
	EEG**	
19	BMR	
	Estimation of total haemoglobin	
	Bicycle ergometry	
	Psychometric tests*	
20	Measurement of isometric muscle strength	
	Roentgenological estimation of heart volume*	
	Discharge from hospital	
180	Admission to hospital	VI
	Roentgenological estimation of heart volume*	
	Bicycle ergometry	
	Measurement of isometric muscle strength	
	EEG**	
181	BMR	
	Estimation of total haemoglobin	
	Psychometric tests*	
	Discharge from hospital	

* Results will be reported separately. The psychiatric and psychometric investigations were performed by Curt Rosman, M. D. and the roentgenlogical examination by Kjell Bergström, M.D. and Uno Eriksson, M.D.

** Only of the first 30 patients.

Table 2.

Some anthropological data for the patients in the total series.

	Age (years)	Height (cm)	Weight (kg)	BSA (m^2)
M	73.2	172.4	74.4	1.86
SD	5.8	5.2	10.7	0.14
SEM	0.62	0.56	1.15	0.015
range	60–86	162–184	51.5–99.2	1.57–2.20
n	86	86	86	86

Table 3.

Duration of operation in minutes (a), peroperative blood loss (b), blood loss from end of operation to ex. IV (c), blood and dextran substitution during operation (d), blood (and occasionally dextran) substitution from end of operation to ex. IV (e), replaced blood loss during operation (f), replaced blood loss at ex. IV (g), invertose-electrolyte solutions given until ex. IV (h). Volumes are expressed in ml.

	a	b	c	d	e	f	g	h
n	86	86	84	86	85	85	83	85
M	88	1050	582	1353	730	+234*)	+370**)	2326
SD	47	2140	880	2110	1148	336	2059	978
SEM	5.1	231	96	228	125	36	226	106
range	50— −405	118— −19000	20— −3600	400— −19600	0— −6000	−960— +790	−2000— +2460	700— −4500

*) thereof 330 ml dextran.
**) thereof 344 ml dextran.

Table 4.

Investigation programme at ex. II, III and IV.

Recording of rectal temperature, room temperature and barometer reading.

Air breathing with collection of expired gas and blood samples from the catheters in radial and pulmonary arteries.

Oxygen breathing with continuous analysis of expired gas and collection of blood samples at $F_{A_{N_2}} \leq 2$ per cent or stable value.

Determination of peak expiratory flow.

Table 5.

$\dot{V}_{O_2}$ before and after operation. Values in relative terms (per cent of value at ex. I) and in absolute terms (ml STPD/min·m² BSA)—the latter in brackets.

Ex	M	SD	SEM	range	n	S
I	100					
	(118.7)	(13.8)	(1.49)	(82.1–157.1)	(86)	
II	105.4	13.4	1.47	76.2–152.2	83	xxx
	(124.0)	(13.3)	(1.47)	(88.8–152.3)	(83)	
III	142.3	51.4	5.71	88.2–380.3	81	xxx
	(167.3)	(60.7)	(6.74)	(99.5–481.8)	(81)	
IV	121.6	23.8	2.58	79.3–223.5	84	xxx
	(142.6)	(23.3)	(2.53)	(96.9–261.5)	(85)	
V	102.2	11.4	1.30	78.2–135.3	77	NS
	(121.0)	(12.5)	(1.43)	(91.5–158.2)	(77)	

Table 6.

t_{rect} before and after operation. Values in relative terms (change in °C from ex. II) and in absolute terms (°C)—the latter in brackets.

Ex	M	SD	SEM	range	n	S
II	0					
	(36.9)	(0.27)	(0.029)	(36.2–37.5)	(86)	
III	−1.01	0.69	0.079	−3.2–+0.3	76	xxx
	(35.9)	(0.76)	(0.087)	(33.7– 37.6)	(76)	
IV	+0.81	0.57	0.061	−0.1–+2.4	86	xxx
	(37.7)	(0.59)	(0.064)	(36.2– 39.4)	(86)	

Table 7.

Pa_{CO_2} before and after operation. Values in relative terms (per cent of value at ex. II) and in absolute terms (mm Hg)—the latter in brackets.

Ex	M	SD	SEM	range	n	S
II	100					
	(38.8)	(4.2)	(0.46)	(30–51)	(86)	
III	104.6	20.9	2.27	71.8–190.1	85	x
	(40.2)	(6.8)	(0.74)	(31–69)	(85)	
IV	99.2	13.2	1.43	67.9–140.1	85	NS
	(38.2)	(4.5)	(0.49)	(25–50)	(85)	

Table 8.

$\dot{V}_E$ before and after operation. Values in relative terms (per cent of value at ex. II) and in absolute terms (l BTPS/min)—the latter in brackets.

Ex	M	SD	SEM	range	n	S
II	100 (7.67)	(1.22)	(0.13	(5.37–11.95)	(84)	
III	136.8 (10.33)	59.3 (3.88)	6.59 (0.43)	65.6–482.6 (5.23–32.96)	81 (81)	xxx
IV	130.2 (9.87)	28.8 (1.90)	3.14 (0.21)	69.9–238.8 (6.74–16.31)	84 (85)	xxx

Table 9.

$\dot{V}_A$ before and after operation. Values in relative terms (per cent of value at ex. II) and in absolute terms (l BTPS/min)—the latter in brackets.

Ex	M	SD	SEM	range	n	S
II	100 (4.72)	(0.96)	(0.11)	(3.26–7.72)	(83)	
III	143.2 (6.54)	75.5 (2.92)	8.44 (0.33)	37.7–565.6 (2.85–23.10)	80 (81)	xxx
IV	126.4 (5.78)	33.2 (1.24)	3.67 (0.13)	57.6 –250.6 (3.56–10.24)	82 (84)	xxx

Table 10.

V_T before and after operation. Values in relative terms (per cent of value at ex. II) and in absolute terms (ml BTPS)—the latter in brackets.

Ex	M	SD	SEM	range	n	S
II	100 (512)	(136)	(14.9)	(312–1264)	(83)	
III	116.5 (573)	39.7 (166)	4.44 (18.5)	34.2–231.9 (266–1070)	80 (81)	xxx
IV	102.3 (508)	22.9 (101)	2.51 (11.3)	36.5–150.3 (318–765)	83 (85)	NS

Table 11.

f before and after operation. Values in relative terms (per cent of value at ex. II) and in absolute terms (breaths per minute)—the latter in brackets.

Ex	M	SD	SEM	range	n	S
II	100					
	(15.5)	(3.0)	(0.33)	(9.2– 25.0)	(85)	
III	120.4	37.3	4.07	73.8–200.2	85	xxx
	(18.4)	(4.3)	(0.46)	(12.0– 31.0)	(85)	
IV	131.2	24.3	2.63	83.7–217.7	85	xxx
	(19.9)	(3.5)	(0.38)	(13.8–33.0)	(85)	

Table 12.

R before and after operation. Values in relative terms (per cent of value at ex. II) and in absolute terms ($\dot{V}_{CO_2}/\dot{V}_{O_2}$)—the latter in brackets.

Ex	M	SD	SEM	range	n	S
II	100					
	(0.77)	(0.089)	(0.010)	(0.54–1.14)	(84)	
III	107.0	14.9	1.65	73–147	82	xxx
	(0.81)	(0.101)	(0.011)	(0.52–1.15)	(83)	
IV	104.9	15.2	1.66	54–140	84	xx
	(0.80)	(0.079)	(0.009)	(0.62–1.01)	(85)	

Table 13.

PEF before and after operation. Values in relative terms (per cent of value at ex. II) and in absolute terms (l/min)—the latter in brackets.

Ex	M	SD	SEM	range	n	S
II	100					
	(403)	(106)	(11.6)	(135–630)	(83)	
III	61.2	25.7	3.17	15.2–142.1	66	xxx
	(240)	(96)	(11.8)	(60–420)	(67)	
IV	70.1	22.2	2.55	27.7–152.1	76	xxx
	(276)	(93)	(10.6)	(130–520)	(78)	

Table 14.

Pa_{O_2} before and after operation. Values in relative terms (per cent of value at ex. II) and in absolute terms (mm Hg)—the latter in brackets.

Ex	M	SD	SEM	range	n	S
II	100					
	(77.3)	(9.4)	(1.02)	(60–101)	(85)	
III	90.5	21.3	2.33	48–141	83	
	(69.7)	(13.8)	(1.49)	(32–108)	(85)	xxx
IV	95.3	18.0	1.96	53–145	85	x
	(73.9)	(10.8)	(1.17)	(43–110)	(86)	

Table 15.

$A–aD_{O_2}$ before and after operation. Values in relative terms (changes in mm Hg from ex. II) and in absolute terms (mm Hg)—the latter in brackets.

Ex	M	SD	SEM	range	n	S
II	0					
	(22.4)	(10.2)	(1.12)	(3–47)	(83)	
III	+8.9	14.0	1.56	−38–+45	81	xxx
	(31.0)	(13.6)	(1.49)	(0–58)	(83)	
IV	+6.6	12.4	1.37	−27–+31	82	xxx
	(28.8)	(12.6)	(1.37)	(4–56)	(85)	

Table 16.

V_D before and after operation. Values in relative terms (per cent of value at ex. II) and in absolute terms (ml BTPS)—the latter in brackets.

Ex	M	SD	SEM	range	n	S
II	100					
	(195.6)	(52.9)	(5.81)	(110–444)	(83)	
III	109.0	31.6	3.56	44.8–190.5)	79	x
	(207.4)	(50.0)	(6.67)	(96–379)	(81)	
IV	110.3	27.4	3.02	48.4–232.1	82	xx
	(206.7)	(46.1)	(5.03)	(106–380)	(84)	

TABLE 17.

V_D/V_T before and after operation. Values in relative terms (per cent of value at ex. II) and in absolute terms (per cent)—the latter in brackets.

Ex	M	SD	SEM	range	n	S
II	100					
	(38.6)	(6.48)	(0.71)	(21.4–54.3)	(83)	
II	97.4	22.9	2.57	39.2–166.8	80	NS
	(37.1)	(7.72)	(0.86)	(18.4–62.7)	(81)	
IV	109.6	19.4	2.14	76.1–175.6	82	xxx
	(41.3)	(5.55)	(0.61)	(28.2–56.0)	(84)	

TABLE 18.

$\dot{Q}s/\dot{Q}t$ before and after operation. Values in relative terms (per cent of value at ex. II) and in absolute terms (per cent of cardiac output)—the latter in brackets.

Ex	M	SD	SEM	range	n	S
II	100					
	(8.28)	(4.53)	(0.63)	(2.4–22.9)	(52)	
III	155.2	94.1	13.4	3.3–448.1	49	xxx
	(10.88)	(6.92)	(0.98)	(0.4–33.9)	(50)	
IV	142.4	96.5	13.8	15.9–446.9	49	xx
	(9.25)	(4.33)	(0.61)	(1.3–19.8)	(50)	

TABLE 19.

$\dot{V}_A/\dot{Q}$ before and after operation. Values in relative terms (per cent of value at ex. II) and in absolute terms—the latter in brackets.

Ex	M	SD	SEM	range	n	S
II	100					
	(0.907)	(0.245)	(0.033)	(0.49–1.65)	(55)	
III	127.1	56.4	7.90	50.4–354.1	51	xx
	(1.105)	(0.451)	(0.063)	(0.45–2.53)	(51)	
IV	115.4	33.3	4.58	57.6–231.8	53	xx
	(1.003)	(0.270)	(0.037)	(0.60–1.78)	(53)	

Table 20.

Hb before and after operation. Values in relative terms (per cent of value at ex. II) and in absolute terms (g/100 ml)—the latter in brackets.

Ex	M	SD	SEM	range	n	S
II	100					
	(12.66)	(1.22)	(0.134)	(9.6– 16.1)	(83)	
III	93.9	7.78	0.859	76.2–111.9	82	xxx
	(11.89)	(1.29)	(0.143)	(8.2– 15.3)	(82)	
IV	96.3	8.73	0.964	73.7–124.6	82	xxx
	(12.16)	(1.35)	(0.148)	(8.1– 15.6)	(83)	

Table 21.

Hct before and after operation. Values in relative terms (per cent of value at ex. II) and in absolute terms (per cent)—the latter in brackets.

Ex	M	SD	SEM	range	n	S
II	100					
	(39.2)	(3.5)	(0.39)	(31.0– 48.5)	(80)	
III	94.6	8.7	0.98	71.4 –127.0	78	xxx
	(37.2)	(3.9)	(0.44)	(26.0 – 47.0)	(80)	
IV	96.6	8.7	0.99	73.9 –125.8	77	xxx
	(37.9)	(3.9)	(0.43)	(25.5 – 47.0)	(80)	

Table 22.

Sao_2 before and after operation. Values in relative terms (per cent of value at ex. II) and in absolute terms (per cent)—the latter in brackets.

Ex	M	SD	SEM	range	n	S
II	100					
	(95.2)	(1.89)	(0.22)	(90.6–100.0)	(76)	
III	97.7	7.95	0.92	52.1–108.2	75	x
	(93.0)	(7.54)	(0.87)	(50.1–100.0)	(75)	
IV	98.3	4.30	0.50	70.8–106.7	75	xx
	(93.5)	(3.77)	(0.43)	(67.1– 99.6)	(75)	

Table 23.

$S\bar{v}_{O_2}$ before and after operation. Values in relative terms (per cent of value at ex. II) and in absolute terms (per cent)—the latter in brackets.

Ex	M	SD	SEM	range	n	S
II	100					
	(69.1)	(6.4)	(0.86)	(43.3– 82.6)	(55)	
III	89.3	19.7	2.71	40.2–152.4	53	xxx
	(61.3)	(12.5)	(1.71)	(24.9–83.0)	(53)	
IV	96.0	11.7	1.60	65.1–147.8	53	x
	(65.9)	(6.3)	(0.87)	(45.7– 77.5)	(53)	

Table 24.

Ca_{O_2} before and after operation. Values in relative terms (per cent of value at ex. II) and in absolute terms (ml/100 ml blood)—the latter in brackets.

Ex	M	SD	SEM	range	n	S
II	100					
	(16.52)	(1.58)	(0.18)	(12.50– 20.09)	(75)	
III	90.4	9.67	1.12	48.2 –109.4	74	xxx
	(14.96)	(2.01)	(0.23)	(7.41– 19.73)	(74)	
IV	93.9	6.92	0.81	71.9 –109.8	73	xxx
	(15.49)	(1.72)	(0.20)	(10.71– 19.96)	(73)	

Table 25.

$C\bar{v}_{O_2}$ before and after operation. Values in relative terms (per cent of value at ex. II) and in absolute terms (ml/100 ml blood)—the latter in brackets.

Ex	M	SD	SEM	range	n	S
II	100					
	(11.86)	(1.74)	(0.24)	(6.75– 16.07)	(55)	
III	80.2	18.9	2.60	35.0 –125.7	53	xxx
	(9.58)	(2.26)	(0.31)	(3.38– 15.02)	(53)	
IV	91.3	11.0	1.51	61.8 –124.6	53	xxx
	(10.75)	(1.59)	(0.22)	(7.74– 13.91)	(53)	

Table 26.

AVD_{O_2} before and after operation. Values in relative terms (per cent of value at ex. II) and in absolute terms (ml/100 ml)—the latter in brackets.

Ex	M	SD	SEM	range	n	S
II	100 (4.61)	(1.06)	(0.143)	(2.80– 8.29)	(55)	
III	111.9 (5.04)	40.4 (1.72)	5.55 (0.236)	51.4 –236.5 (2.37–10.00)	53 (53)	x
IV	100.9 (4.52)	22.5 (0.86)	3.09 (0.119)	53.0 –162.2 (3.18– 6.98)	53 (53)	NS

Table 27.

$\dot{Q}$ before and after operation. Values in relative terms (per cent of value at ex. II) and in absolute terms (l/min)—the latter in brackets.

Ex	M	SD	SEM	range	n	S
II	100 (5.25)	(1.37)	(0.184)	(2.9– 10.0)	(55)	
III	129.7 (6.53)	38.6 (1.89)	5.41 (0.265)	57.0–231.9 (2.0– 11.1)	51 (51)	xxx
IV	117.2 (5.95)	28.3 (1.27)	3.88 (0.174)	58.4–171.6 (3.5–8.6)	53 (53)	xxx

Table 28.

$\dot{C}a_{O_2}$ before and after operation. Values in relative terms (per cent of value at ex. II) and in absolute terms (ml/min)—the latter in brackets.

Ex	M	SD	SEM	range	n	S
II	100 (862)	(244)	(32.9)	(417–1860)	(55)	
III	115.3 (960)	37.2 (313)	5.21 (43.8)	52.1–228.0) (311–1936)	51 (51)	xx
IV	108.6 (906)	25.4 (207)	3.49 (28.5)	53.2–165.6 (513–1377)	53 (53)	x

TABLE 29.

O_2uc before and after operation. Values in relative terms (per cent of value at ex. II) and in absolute terms (per cent)—the latter in brackets.

Ex	M	SD	SEM	range	n	S
II	100					
	(28.1)	(6.3)	(0.85)	(15.0– 53.7)	(55)	
III	128.7	43.9	6.15	61.9–272.7	51	xxx
	(35.3)	(11.2)	(1.57)	(13.6– 66.5)	(51)	
IV	108.5	24.0	3.30	61.5–182.6	53	x
	(29.7)	(6.1)	(0.84)	(19.4– 47.4)	(53)	

TABLE 30.

pH_a before and after operation. Values in relative terms (per cent of value at ex. II) and in absolute terms (pH units)—the latter in brackets.

Ex	M	SD	SEM	range	n	S
II	100					
	(7.413)	(0.032)	(0.0035)	(7.34–7.52)	(86)	
III	99.496	0.692	0.0751	97.14–101.01	85	xxx
	(7.376)	(0.045)	(0.0049)	(7.21–7.49)	(85)	
IV	99.843	0.593	0.0640	98.15–102.14	86	x
	(7.401)	(0.041)	(0.0044)	(7.24–7.54)	(86)	

TABLE 31.

HCO_3^- before and after operation. Values in relative terms (per cent of value at ex. II) and in absolute terms (mEq/l)—the latter in brackets.

Ex	M	SD	SEM	range	n	S
II	100					
	(24.2)	(1.74)	(0.19)	(20.5– 29.1)	(86)	
III	94.0	8.45	0.92	77.9–135.7)	85	xxx
	(22.6)	(1.87)	(0.20)	(18.0– 27.3)	(85)	
IV	96.8	13.20	1.42	71.5–161.2	86	x
	(23.2)	(2.42)	(0.26)	(15.9– 31.2)	(86)	

Table 32.

B.E. before and after operation. Values in relative terms (change in mEq/l from ex. II) and in absolute terms (mEq/l)—the latter in brackets.

Ex	M	SD	SEM	range	n	S
II	0 (+0.32)	(2.08)	(0.224)	(−4.8–+5.9)	(86)	
III	−2.07 (−1.75)	1.86 (2.17)	0.201 (0.236)	−6.3–+2.8 (−7.0–+2.9)	85 (85)	xxx
IV	−1.51 (−1.22)	2.51 (3.05)	0.271 (0.329)	−9.5–+9.5 (−11.0–+8.4)	86 (86)	xxx

Table 33.

Number of patients in age groups B_{age} and A_{age} submitted to different types of anaesthesia.

Group	H	C	S
B_{age}	5	6	10
A_{age}	6	8	7

Table 34.

Relative values (M ± SEM) for $\dot{V}_{O_2}$, t_{rect}, Pa_{CO_2} and $\dot{V}_E$ in the two age groups at ex. III and IV.

Parameter	Group	III		IV	
		M±SEM	D	M±SEM	D
$d\dot{V}_{O_2}$, per cent	B_{age}	137.3± 7.1	NS	121.5±7.1	NS
	A_{age}	166.2±16.7		124.0 ±5.3	
d t_{rect}, °C	B_{age}	−0.92± 0.16	NS	+0.84±0.03	NS
	A_{age}	−1.24 ± 0.17		+0.65±0.15	
d Pa_{CO_2}, per cent	B_{age}	104.7± 3.9	x	97.8±2.8	NS
	A_{age}	93.8± 2.9		94.6±3.1	
d $\dot{V}_E$, per cent	B_{age}	136.8± 5.8	NS	129.1±4.9	NS
	A_{age}	167.3±20.0		140.6±7.6	

Table 35.

Relative values (M±SEM) for *alveolo-arterial oxygen transport* parameters in the two age groups at ex. III and IV.

Parameter	Group	III		IV	
		M±SEM	D	M±SEM	D
dPa_{O_2}, per cent....	B_{age}.....	92.4±3.6	NS	97.0 ±2.6	NS
	A_{age}.....	92.4±4.1		99.3 ±4.1	
$dA\text{-}aD_{O_2}$, mm Hg.	B_{age}.....	+8.5±2.7	NS	+6.1±2.5	NS
	A_{age}.....	+12.1±3.3		+9.0±3.2	
dV_D, per cent.....	B_{age}.....	115.1±6.0	NS	114.6±8.2	NS
	A_{age}.....	118.3±6.3		115.2±3.8	
dV_D/V_T, per cent..	B_{age}.....	100.1±5.4	NS	111.5±6.1	NS
	A_{age}.....	88.7±5.0		101.4±2.6	
$d\dot{Q}s/\dot{Q}t$, per cent...	B_{age}.....	139.1±23.1	NS	125.4±22.8	NS
	A_{age}.....	133.4±22.9		117.0±16.1	

Table 36.

Relative values (M±SEM) for *oxygen transport in blood* parameters and B.E. in arterial blood in the two age groups at ex. III and IV.

Parameter	Group	III		IV	
		M±SEM	D	M±SEM	D
$dAVD_{O_2}$, per cent.	B_{age}.....	114.5±8.2	NS	100.8±7.5	NS
	A_{age}.....	125.5±13.1		101.6±5.1	
$d\dot{Q}$, per cent.....	B_{age}.....	113.6±7.3	NS	113.4±11.5	NS
	A_{age}.....	133.9±9.4		122.8±5.8	
$d\dot{C}\ a_O$, per cent...	B_{age}.....	100.5±6.6	NS	106.2±10.1	NS
	A_{age}.....	121.5±8.8		112.8± 5.9	
dO_2 uc, per cent....	B_{age}.....	130.8± 9.8	NS	107.3±7.7	NS
	A_{age}.....	138.4±15.4		111.2±6.3	
dB.E., mEq/l.....	B_{age}.....	−1.49±0.38	x	−1.56±0.42	NS
	A_{age}.....	−2.81±0.46		−2.04±0.54	

Table 37.

Some data for groups A_{vent} and B_{vent}. (Grouped according to ventilatory state).

Group		M±SEM	range
A_{vent}	Age, years	74.1±1.0	61– 86
	VC, per cent of predicted	94.5±1.5	80–113
	$FEV_{1.0}$, per cent of predicted	95.2±2.1	80–120
B_{vent}	Age, years	73.0±1.1	60– 83
	VC, per cent of predicted	73.4±2.1	55–104
	$FEV_{1.0}$, per cent of predicted	58.1±2.2	33– 79

Table 38.

Number of patients in groups A_{vent} and B_{vent} submitted to different types of anaesthesia.

Group	H	C	S
A_{vent}	9	15	6
B_{vent}	10	8	12

Table 39.

Relative values (M±SEM) for *oxygenation of blood* parameters at ex. III and IV in groups A_{vent} and B_{vent}.

Parameter	Group	III		IV	
		M±SEM	D	M±SEM	D
dPa_{CO_2}, per cent...	A_{vent}.....	103.3±3.8	NS	102.7±2.5	NS
	B_{vent}.....	107.8±3.9		98.8±2.3	
$d\dot{V}_E$, per cent.....	A_{vent}.....	152.2±16.4	NS	129.2±6.3	NS
	B_{vent}.....	129.0± 6.1		132.2±4.8	
dV_T, per cent.....	A_{vent}.....	125.9±9.0	NS	100.9±4.4	NS
	B_{vent}.....	107.9±5.2		101.6±4.0	
dPEF, per cent....	A_{vent}.....	51.6±3.8	NS	64.7±3.6	x
	B_{vent}.....	67.7±7.6		78.3±5.2	
dPa_{O_2}, per cent....	A_{vent}.....	94.8±3.7	NS	96.8±2.4	NS
	B_{vent}.....	88.3±3.5		96.4±3.0	
$dA–aD_{O_2}$, mm Hg.	A_{vent}.....	+8.6±2.9	NS	+5.0±2.2	NS
	B_{vent}.....	+8.0±2.1		+5.9±2.4	
dV_D, per cent.....	A_{vent}.....	110.0±6.5	NS	110.2±6.0	NS
	B_{vent}.....	112.3±5.9		109.6±4.3	
dV_D/V_T, per cent..	A_{vent}.....	93.3±4.2	x	111.9±3.9	NS
	B_{vent}.....	105.6±4.1		108.3±3.0	
$d\dot{Q}s/\dot{Q}t$, per cent...	A_{vent}.....	133.9±21.0	NS	134.6±23.6	NS
	B_{vent}.....	188.3±30.2		165.3±31.1	

Table 40.

Age (M±SEM), total number of patients and number of patients submitted to different types of anaesthesia in the A_w and B_w groups (grouped according to working capacity).

Group	Age	n	H	C	S
A_w.....	70.8±1.0	29	9	10	10
B_w.....	76.3±1.2	21	7	5	9

TABLE 41.

Relative values (M±SEM) for $\dot{V}_{O_2}$, *alveolo-arterial oxygen transport* and *oxygen transport in blood* parameters at ex. III and IV in groups A_w and B_w.

Parameter	Group	III		IV	
		M±SEM	D	M±SEM	D
$d\dot{V}_{O_2}$, per cent.....	A_w.....	150.3±11.6	NS	120.5±4.6	NS
	B_w.....	138.7±12.0		120.8±5.6	
dPa_{O_2}, per cent....	A_w.....	89.7±3.5	NS	99.1±2.5	NS
	B_w.....	95.4±4.8		92.1±3.0	
$d\dot{Q}s/\dot{Q}t$, per cent...	A_w.....	176.0±24.4	NS	133.4±21.5	NS
	B_w.....	150.6±27.2		159.1±29.9	
$dS\bar{v}_{O_2}$, per cent....	A_w.....	91.3±4.1	NS	94.1±7.2	NS
	B_w.....	94.1±7.2		96.5±5.3	
$dAVD_{O_2}$, per cent..	A_w.....	110.0±9.6	NS	99.2±3.8	NS
	B_w.....	104.0±12.4		98.5±7.1	
$d\dot{Q}$, per cent.....	A_w.....	142.3±9.7	NS	123.4±6.4	NS
	B_w.....	124.6±7.5		110.8±9.1	
$d\dot{C}a_{O_2}$, per cent....	A_w.....	127.2±9.2	NS	115.7±5.4	NS
	B_w.....	109.3±7.7		100.6±7.3	
dO_2 uc, per cent...	A_w.....	126.5±10.2	NS	104.3±3.0	NS
	B_w.....	126.2±16.9		107.2±7.2	

TABLE 42.

Some anthropological data (M±SEM) for patients in groups H, C and S.

Group	Age (years)	Height (cm)	Weight (kg)	BSA (m^2)	n
H.....	73.6±1.1	172.6±1.1	74.6±2.0	1.87±0.03	28
C.....	73.4±1.2	171.0±0.9	74.5±2.0	1.86±0.03	27
S.....	72.8±1.0	172.4±1.0	73.6±2.1	1.86±0.03	29

Table 43.

Significances of differences between relative values for $\dot{V}_{O_2}$, t_{rect} and ventilatory parameters in groups H, C and S at pre-, per- and postoperative examinations.

Ex.	$d\dot{V}_{O_2}$	dt_{rect}	dPa_{CO_2}	$d\dot{V}_E$	$d\dot{V}_A$	dV_T	df	dR	dPEF
II	$H>S^x$ $C>S^x$	–	–	–	–	–	–	–	–
OP	–	–	$H>C^{xxx}$ $H>S^{xxx}$ $S>C^{xxx}$	–	–	–	–	–	–
III	$C>S^x$	NS	$H>C^x$ $H>S^{xxx}$ $C>S^x$	NS	NS	$C>H^{xx}$ $S>H^x$	$H>S^x$	NS	$S>H^{xxx}$ $S>C^{xxx}$
IV	NS	NS	$C>Ss^{xx}$	$Ss>H^x$	$Ss>H^{xx}$	NS	NS	$Se>H^x$	$Se>H^x$ $Se>C^{xx}$
V	$H>S^x$ $C>S^{xxx}$	–	–	–	–	–	–	–	–

Table 44.

Significances of differences between relative values for *oxygenation of blood* parameters in groups H, C and S at per- and postoperative examinations.

Ex.	dPa_{O_2}	$dA\text{–}aD_{O_2}$	dV_D	dV_D/V_T	$d\dot{Q}s/\dot{Q}t$	$d\dot{V}_A/\dot{Q}$
OP	$H>C^{xxx}$ $H>S^{xxx}$	–	–	–	–	–
III	$S>H^{xxx}$ $S>C^{xx}$	$H>S^x$ $C>S^x$	NS	NS	$H>S^{xx}$	$C>H^x$ $C>S^x$
IV	$Ss>H^x$ $Ss>C^{xx}$	$C>Ss^x$	NS	$H>Ss^x$ $C>Ss^x$	NS	NS

Table 45.

Significances of differences between relative values for *oxygen transport in blood* parameters in groups H, C and S at postoperative examinations.

Ex.	dSa_{O_2}	$dS\bar{v}_{O_2}$	dCa_{O_2}	$dC\bar{v}_{O_2}$	$dAVD_{O_2}$	$d\dot{Q}$	$d\dot{C}a_{O_2}$	dO_2uc
III	$S>H^{xx}$ $S>C^{xx}$	$S>H^x$ $S>C^{xxx}$	NS	$S>C^{xxx}$	$C>H^{xxx}$ $C>S^{xxx}$	NS	NS	$C>H^x$ $C>S^{xxx}$
IV	NS	NS	$Ss>Se^x$	NS	NS	$Se>H^x$	$Se>H^x$	NS

Table 46.

Significances of differences between relative values for *acid-base balance in arterial blood* parameters in groups H, C and S at per- and postoperative examinations.

Ex.	d pH_a	d HCO_3^-	d B.E.
OP	$C>H^{xxx}$ $C>S^{xxx}$ $S>H^{xxx}$	NS	$C>H^{xx}$
III	$C>H^{xx}$ $S>H^{xxx}$ $S>C^{x}$	NS	NS
IV	NS	$C>H^{x}$ $C>Se^{x}$	$C>Se^{x}$

Table 47.

Peroperative (ex. II–III) and postoperative (ex. III–IV) blood loss in ml. in groups H, C and S.

	Group	M±SEM	D
Peroperative blood loss	H	660± 68	$C>H^{x}$
	C	1345±259	$C>S^{x}$
	S	672± 93	
Postoperative blood loss	H	655±190	NS
	C	497±130	
	Ss	811±314	
	Se	274±136	

Table 48.

Some data (M±SEM) for groups B_{bl} and A_{bl} (grouped according to blood loss).

Group	Age, years	d Hb, per cent	Blood loss, ml	Replaced blood loss, ml
B_{bl}III	72.0±1.2	93.2±1.6	322± 19	+325± 48
B_{bl}IV	71.6±1.1	97.1±1.4	475± 26	+329± 51
A_{bl}III	74.9±1.1	92.1±1.4	1534±212	+96± 74
A_{bl}IV	75.7±1.0	93.6±1.8	3358±695	+386±171

TABLE 49.

Number of patients in groups B_{bl} and A_{bl} submitted to different types of anaesthesia.

Groups	H	C	S
B_{bl}III	12	4	14
A_{bl}III	10	12	8
B_{bl}IV	12	6	12
A_{bl}IV	10	11	9

TABLE 50.

Relative values (M±SEM) for $\dot{V}_{O_2}$, t_{rect} and ventilatory parameters at ex. III and IV in groups B_{bl} and A_{bl}.

Parameter	Group	III		IV	
		M±SEM	D	M±SEM	D
d $\dot{V}_{O_2}$, per cent	B_{bl}	130.0±5.7	xx	121.8±4.1	NS
	A_{bl}	167.6±13.1		122.5±4.4	
d t_{rect}, °c	B_{bl}	−0.87±0.13	NS	+0.93±0.09	NS
	A_{bl}	−1.17±0.14		+0.79±0.13	
d Pa_{CO_2}, per cent	B_{bl}	104.4±4.1	NS	100.0±1.7	NS
	A_{bl}	104.5±3.9		99.1±3.1	
d $\dot{V}_E$, per cent	B_{bl}	122.9±6.0	x	124.0±4.5	NS
	A_{bl}	163.8±15.6		135.4±6.4	

TABLE 51.

Relative values (M±SEM) for *alveolo-arterial oxygen transport* parameters at ex. III and IV in groups B_{bl} and A_{bl}.

Parameter	Group	III		IV	
		M±SEM	D	M±SEM	D
d Pa_{O_2}, per cent....	B_{bl}.....	96.0±3.7	NS	95.8±2.6	NS
	A_{bl}.....	90.3±3.4		95.5±3.3	
d A–aD_{O_2}, mm Hg.	B_{bl}.....	+6.6±2.7	NS	+6.1±2.6	NS
	A_{bl}.....	+8.3±2.8		+8.4±2.5	
d V_D, per cent.....	B_{bl}.....	99.2±5.2	xx	103.6±4.8	NS
	A_{bl}.....	123.5±6.3		110.9±3.5	
d V_D/V_T, per cent..	B_{bl}.....	95.8±4.2	NS	105.7±2.7	NS
	A_{bl}.....	95.8±3.5		110.9±3.8	
d $\dot{Q}s/\dot{Q}t$, per cent...	B_{bl}.....	159.6±17.3	NS	164.2±29.8	NS
	A_{bl}.....	127.4±20.3		106.6±14.0	

TABLE 52.

Relative values (M±SEM) for *oxygen transport in blood* parameters and B.E. at ex. III and IV in groups B_{bl} and A_{bl}.

Parameter	Group	III		IV	
		M±SEM	D	M±SEM	D
d Sa_{O_2}, per cent....	B_{bl}.....	99.2±0.7	NS	98.2±0.5	NS
	A_{bl}.....	97.2±2.1		98.1±1.1	
d $S\bar{v}_{O_2}$, per cent....	B_{bl}.....	100.6±4.4	xx	101.1±4.1	NS
	A_{bl}.....	82.6±3.9		91.8±2.3	
d AVD_{O_2}, per cents.	B_{bl}.....	94.5±7.1	xx	93.8±6.5	NS
	A_{bl}.....	124.5±9.2		106.5±5.3	
d $\dot{Q}$, per cent.....	B_{bl}.....	138.1±9.7	NS	130.2±9.2	NS
	A_{bl}.....	129.0±7.3		110.0±5.8	
d $\dot{C}a_{O_2}$, per cent...	B_{bl}.....	119.8±8.2	NS	119.2±8.3	x
	A_{bl}.....	114.4±7.1		99.9±4.9	
d O_2 uc, per cent...	B_{bl}.....	108.0±7.5	xx	102.0±6.8	NS
	A_{bl}.....	144.4±10.2		117.6±5.7	
d B.E., mEq/l.....	B_{bl}.....	−2.2±0.3	NS	−2.4±0.5	NS
	A_{bl}.....	−2.2±0.4		−0.8±0.7	

TABLE 53.

Relative values (M±SEM) for $\dot{V}_{O_2}$, V_D and *oxygen transport in blood* parameters at ex. III in groups b_{bl} and a_{bl} (grouped according to blood loss and anaesthesia, see p. 40).

Parameter	Group	III	
		M±SEM	D
d $\dot{V}_{O_2}$, per cent....	b_{bl}.....	135.1± 6.3	x
	a_{bl}.....	163.2±12.9	
d V_D, per cent.....	b_{bl}.....	101.3±5.7	NS
	a_{bl}.....	117.4±6.0	
d $S\bar{v}_{O_2}$, per cent....	b_{bl}.....	93.6±5.7	NS
	a_{bl}.....	83.3±4.1	
d AVD_{O_2}, per cent.	b_{bl}.....	103.3±8.6	NS
	a_{bl}.....	122.7±9.4	
d O_2 uc, per cent...	b_{bl}.....	118.5± 9.5	NS
	a_{bl}.....	142.8±10.5	

Table 54.

$\dot{V}_{O_2}$ and ventilatory parameters in elderly persons according to different authors. $\dot{V}_{O_2}$ in ml STPD/min·m² BSA, Pa_{CO_2} in mm Hg, $\dot{V}_E$ and $\dot{V}_A$ in l BTPS/min, f in breaths/min and R in $\dot{V}_{CO_2}/\dot{V}_{O_2}$.

Author	Mean age: (years)	Sex	$\dot{V}_{O_2}$	Pa_{CO_2}	$\dot{V}_E$	$\dot{V}_A$	V_T	f	R
Robinson (1938) [104]	75	♂	114	–	6.9	–	510	13.7	–
Greifenstein et al. (1952) [54]	50	♂♀	–	38.8	6.1[w]	–	343[y]	19	–
Shock & Yiengst (1955) [115]	70–79	♂	113	–	6.9	–	377	18.8	0.80
Tenney & Miller (1956) [132]	78.4	♂♀	123	38	9.3	4.9	492	19	0.9
Raine & Bishop (1963) [101]	48.1	♂♀	244[z]	34.5	8.4	–	536	16.7	0.81
Ulmer & Reichel (1963) [135]	68.9	♂	–	38.8	–	–	–	–	–
Granath et al. (1964) [50, 51]	70.5	♂	255[z]	–	8.7	–	–	–	–
Ward et al (1966) [139]	74.6	♂	–	32.8	–	–	–	–	–
Renck present study	73.2	♂	119	38.8	7.7	4.7	512	15.5	0.77

[z] ml STPD/min
[w] l BTPS/min·m² BSA
[y] ml BTPS/min·m² BSA

Table 55.

Alveolo-arterial oxygen transport parameters in elderly persons according to different authors. Pa_{O_2} and $A\text{-}aD_{O_2}$ in mmHg, V_D in ml BTPS, V_D/V_T and $\dot{Q}s/\dot{Q}t$ in per cent.

Author	Mean age (years)	Sex	Pa_{O_2}	$A\text{-}aD_{O_2}$	V_D	V_D/V_T	$\dot{Q}s/\dot{Q}t$
Tenney & Miller (1956) [132]	78.4	♂♀	–	–	235	47.9*)	–
Cole & Bishop (1963) [31]	50–59	♂	–	18.4	–	27.7	–
Raine & Bishop (1963) [101]	48.1	♂♀	103.9	15.6	124	23.8	–
Ulmer & Reichel (1963) [135]	68.9	♂	79.7	–	–	–	–
Ward et al (1966) [139]	74.6	♂	–	–	–	–	12.7
Renck present study	73.2	♂	77.3	22.4	196	38.6	8.3

*) calculated from mean values.

Table 56.

Oxygen transport in blood parameters in elderly persons according to different authors. Hb in g/100 ml, hct in per cent, S in per cent, Ca_{O_2} and AVD_{O_2} in ml/100 ml and $\dot{Q}$ in l/min.

Author	Mean age (years)	Sex	Hb	Hct	Sa_{O_2}	$S\bar{v}_{O_2}$	Ca_{O_2}	AVD_{O_2}	$\dot{Q}$
Troell (1952) [134] . . .	61	♂♀	–	–	91	70	–	3.30	6.2
Tenney & Miller (1956) [132]	78.4	♂♀	13.0	–	90	–	14.99	–	–
Irnell (1964) [70]	50–59	♂[y])	14.6[q])	–	94.6	67.8	18.48	4.87	4.8
Strandell (1964)[51, 127] . .	70.5	♂	13.3	–	96.3	73.5	–	4.48	5.78
Emirgil et al. (1967) [38] . . .	66	♂♀	–	–	–	–	–	3.7	3.58[w])
Vellar (1967) [136]	70–74	♂	14.8	44.8	–	–	–	–	–
Renck present study	73.2	♂	12.7	39.2	95.2	69.1	16.52	4.61	5.3

[y]) symptom-free asthmatic patients (group A according to Irnell)
[q]) 60–68 years old
[w]) l/min × m^2 BSA

Table 57.

Mean changes of Pa_{O_2} (mm Hg), compared with preoperatively, within an hour after completion of different types of anaesthesia, according to different authors.

Author	H	C	S
Boutros (1965) [22]		–13.8	
Marshall & Millar (1965) [84]	–10		
Fairley et al. (1968) [42]	–13.2		
Kennedy et al. (1968) [74]			+4.4
Renck present study	–14.0	–12.4	+2.0

Table 58.

Mean changes of pH_a (in pH units), compared with preoperatively, within 30 minutes after completion of different types of anaesthesia, according to different authors.

Author	H	C	S
Holmdahl & Payne (1960) [68]	−0.010		
Moir & Mone (1964) [89]			±0.00*)
Moir & Mone (1964) [89]			−0.20**)
Taylor et al. (1964) [131]	−0.077		
Boutros (1965) [22]		−0.075	
Millar & Marshall (1965) [88]	−0.078		
Ivanov et al. (1967) [71]	+0.026		
Kennedy et al. (1968) [74]			−0.018
Renck present study	−0.071	−0.035	−0.009

*) During epidural anaesthesia in patients with healthy lungs.
**) During epidural anaesthesia in patients with lung disease.

Table 59.

Mean changes of HCO_3^- (in mEq/l), compared with preoperatively, within 30 minutes after completion of different types of anaesthesia, according to different authors.

Author	H	C	S
Holmdahl & Payne (1960) [68]	+0.7		
Moir & Mone (1964) [89]			−0.5*)
Millar & Marshall (1965) [88]	−1.29		
Renck present study	−1.74	−1.90	−1.36

*) During epidural anaesthesia in patients with healthy lungs *and* in patients with lung disease.

TABLE 60.

Number of patients submitted to bicycle ergometry and determinations of isometric muscle strength at the different pre- and postoperative examinations.

Ex. no.		Bicycle ergometry	Isometric muscle strength
I	Patients not examined (case nos.)	18, 24, 47, 75	1, 2, 3, 4, 5, 7, 10, 12, 24, 47, 75
	Total number of patients examined	82	75
V	Patients not followed up (case nos.)	1, 11, 20, 29, 43, 64, 86	6, 11, 12, 20, 25, 29, 33, 35, 37, 39, 43, 51
	Total number of patients followed up	75	63
VI	Patients not followed up (case nos.)	11, 20, 29, 30, 32, 48, 50, 51, 54, 67	6, 11, 20, 26, 29, 30, 32, 48, 50, 54, 67
	Total number of patients followed up	72	64

Table 61.
Mortality between ex. I and ex. VI.

Case no.	Age (yrs)	Case history
20	60	Reoperation on the sixth day postoperatively because of bilateral ureteric obstruction of unclear origin as a suspected cause of anuria and uremia. Died on the operating table of circulatory insufficiency.
24	76	Operation complemented with bilateral ligation of the internal iliac artery + bilateral ureterostomy in situ + tamponade of the prostatic bed. Readmitted to hospital about six weeks postoperatively and died about six months later of liver failure, probably due to complication of transfusion.
29	76	Because of persistent bleeding, immediate reoperation with bilateral ligation of internal iliac cartery + ureterotomy in situ + tamponade of prostatic bed. Total operation time about 11 hours. During this period received 49 units of 400 ml blood. Postoperatively, general condition poor and given respirator treatment. Satisfactorily mobilized after about 10 days. After removal of ureteric catheters a proteus sepsis became manifest and despite intensive therapy, septic shock with myocardial infarction. Died 20 days postoperatively.
30	74	Died at home 4 months postoperatively. Autopsy not performed—probably cardiac failure.
32	75	Died 6 months postoperatively of extensive metastases from carcinoma of the prostate.

TABLE 62.
Noteworthy findings in case history.

Case no.	Age (yrs)	Case history
1	75	Bronchial asthma since the age of 53 years. Frequent periods of hospitalization for this condition until at 71 years he was given steroid medication, after which he was essentially symptom-free. Preoperative spirometry (see p. 22): VC 88 per cent, $FEV_{1.0}$ 54 per cent and $FEV_{1.0}/VC$ ratio 59 per cent of predicted.
13	64	At 62 years a heart volume of 830 ml/m² BSA was noted; subjectively no symptoms. Treated at Department of Medicine, University Hospital, Upsala, the following year for chronic rheumatic endocarditis with mitral stenosis (?) and insufficiency and atrial fibrillation. The roentgenological heart volume was then 740 ml/m² BSA. DC regulation was performed. Because of the patient's age a cardiac operation was considered contraindicated. Preop. $W_{max.perf}$ 367 kpm/min and W_{lact} 419 kpm/min.
21	66	Bilateral pulmonary tuberculosis since 29 years old. Because of progression of this disease a right-sided thoracoplasty was performed in three stages at the age of 49 years, 7 ribs being removed. Subsequent clinical healing. Preoperative spirometry (see p. 22): VC 66 per cent, $FEV_{1.0}$ 55 per cent and $FEV_{1.0}/VC$ ratio 80 per cent of predicted. 15 months after the prostatectomy, symptoms of bronchial obstruction and profuse tubercle bacilli in the sputum were observed. Treated for 4 months at the lung clinic, University Hospital, Upsala, under the diagnosis of pulmonary tuberculosis + post-thoracoplasty status + bronchial tuberculosis.
48	74	4 months before prostatectomy he had sought medical advice for respiratory symptoms. Dyspnoea at rest and blood pressure 235/135 mm Hg were noted. Digitalized. Some days afterwards, cystopyelitis with a rectal temperature of over 40° C—treated with indwelling catheter. A few days later, syncope at home. After admission to hospital, the blood pressure was 95/65 mm Hg, potassium in serum 2.8 mEq/l and creatinine in serum 2.2 mg/100 ml. Considered to have had postrenal uremia followed by polyuria after drainage, with hypokalemia. Prostatectomized 2 months later (see also Table 63).
78	68	Five months before prostatectomy, urinary tract infection with oliguria. Creatinine in serum 15.1 mg/100 ml—haemodialysis. When the renal function, body weight and subjective physical capabilities had returned to normal, prostatectomy was performed with a smooth postoperative course.

TABLE 63.

Noteworthy postoperative cardiovascular and other complications.

Case no.	Age (yrs)	Complication
11	76	Had had cardiosclerosis and obstructive pulmonary disease for at least 10 years. Postoperatively, bronchopneumonia and clinical signs of suspected pulmonary embolism. Later in the postoperative course, leg thrombosis and further suspected pulmonary embolism as well as epididymitis. Two years postoperatively there was still slight incontinence of urine and a urethral stricture which was treated in the outpatient department. Not examined at ex. VI because of cardiopulmonary symptoms.
12	74	Clinical and ECG signs of pulmonary embolism in the evening after bicycle ergometry at ex. V. Fairly smooth clinical course. Symptom-free at ex. VI, with increased physical capability.
18	78	Probable ECG indications of anterior wall infarction at ex. VI, acquired since the preoperative examination. Subjectively free from symptoms.
29	76	Myocardial infarction which occurred in connection with septic shock. Verified at autopsy.
43	86	Operation complemented with tamponade of prostatic bed. Pulmonary embolus on 10th day postoperatively, initially with poor general condition. Fairly smooth course subsequently. Subjectively free from symptoms, but physical working capacity slightly reduced at ex. VI.
46	72	Clinical signs of thrombosis in lower left leg.
48	74	Postoperatively, clinical signs of thrombosis in lower left leg. A few days after discharge from hospital, acute cardiac decompensation after physical effort. ECG showed left bundle branch block as before plus newly aquired tachycardia. No transaminase increase. Subjectively unchanged physical working capacity postoperatively. Exercise test not performed at ex. VI because of cardiac decompensation.
62	72	Respiratory arrest with unmeasurable blood pressure immediately after the operation (see p. 18). Considerable increase of physical capability at ex. VI, compared with the preoperative condition.
71	83	A few days after discharge from hospital, dry cough and pain on inspiration after physical effort. ECG showed fresh anterior wall infarction. Subsequently, increasing cerebral disorder with confusion, dementia and incontinence of urine and faeces. Total amnesia for two months and partial amnesia for four months. At ex. VI, remarkable physical and mental restitution with social readaptation. Active physical training commenced.

Table 63 (cont.).

Case no.	Age (yrs)	Complication
86	78	ECG at ex. V showed unexpected signs of fresh anterior wall infarction. Subjectively, negligible transient retrosternal pain about the 3rd–5th day postoperatively. At ex. VI, subjectively and objectively considerably increased physical working capacity and muscle strength.

Table 64.

Body weight (kg) before and after operation. Relative mean values, in per cent of initial value at ex. I, are given in italics.

Ex.	n	M±SEM	range
I	86	74.4±1.2 *100*	52–99
V	80	72.1±1.2 *97.0*^{xxx}	51–96
VI	75	74.7±1.3 *101.3*^{x}	53–97

TABLE

Isometric muscle strength (tests no 1, 2, 30 and 31 in kp, 24 and 25 in kpcm) before and

Ex.	Test no. 1, horizontal pull			Test no. 2, horizontal push			Test no. 24, knee flexion		
	n	M±SEM	range	n	M±SEM	range	n	M±SEM	range
I dx	75	33.6±0.8 *100*	15–54	75	29.0±0.8 *100*	14–49	74	639±23 *100*	198–1008
sin	74	33.2±0.8 *100*	15–52	75	28.3±0.7 *100*	12–46	74	590±19 *100*	176– 940
V dx.	64	31.0±1.0 *90.7*^{xxx}	9–51	64	27.0±0.8 *91.6*^{xxx}	12–43	63	591±24 *90.7*^{xxx}	72– 945
sin	63	31.2±0.8 *93.3*^{xxx}	15–52	64	25.9±0.7 *90.8*^{xxx}	11–42	63	557±21 *93.6*^{xx}	207– 920
VI dx	63	34.8±1.0 *105.4*^{xx}	19–56	63	30.3±1.0 *105.2*^{xx}	12–51	63	649±25 *104.9*^{NS}	192–1218
sin	63	34.6±0.9 *106.5*^{xx}	17–54	64	28.9±0.9 *103.1*^{xx}	12–54	64	604±21 *107.0*^{xx}	328–1026

TABLE 66.

Muscle strenght index before and after operation. The value is given as the mean value for the strength in all muscle groups examined at ex. V and ex. VI, the individual muscle strength value being expressed in per cent of the result at the preoperative examination.

Ex	n	M±SEM	range
I	75	100	
V	63	87.4^{xxx}±1.2	48–105
VI	64	105.4^{xxx}±1.5	77–137

65.

after operation. Relative mean values, in per cent of value at ex. I, are given in italics.

Test no. 25, knee extension			Test no. 30, forward flexion of the trunk			Test no. 31, backward extension of the trunk		
n	M±SEM	range	n	M±SEM	range	n	M±SEM	range
74	1897±61 *100*	800–3276	74	48.1±1.3 *100*	17–75	74	57.2±2.0 *100*	14–108
74	1928±76 *100*	750–4620						
63	1592±63 *84.1*^{xxx}	620–2700	62 *61*	39.5±1.5 *82.4*^{xxx}	18–66	59 *58*	40.6±2.0 *71.3*^{xxx}	9– 84
63	1639±77 *86.4*^{xxx}	713-3822						
63	1875±63 *103.7*^{NS}	871–3045	62 *61*	49.6±1.4 *106.4*^{xxx}	23–78	61 *60*	61.5±2.6 *112.1*^{xxx}	23–115
63	1870±71 *102.4*^{NS}	860–3730						

Table 67.

Haemoglobin concentration in capillary blood (g/100 ml blood), total haemoglobin (g) and total blood volume (l) before and after operation. Relative mean values, in per cent of initial value at ex. I, are given in italics.

Ex.	Hb			THb			TBV		
	n	M±SEM	range	n	M±SEM	range	n	M±SEM	range
I	81	13.2±0.2 *100*	9.3–16.9	72	675±13 *100*	443–950	72	5.6±0.1 *100*	4.1–7.1
V	77 *76*	11.6±0.1 *87.9*^{xxx}	8.6–14.8	66 *57*	584±14 *86.6*^{xxx}	414–1003	66 *57*	5.6±0.1 *98.6*^{NS}	3.8–8.2
VI	72 72	13.6±0.1 *102.5*^{NS}	11.7–16.4	65 *57*	670±13 *100.2*^{NS}	450–999	65 *57*	5.5±0.1 *99.2*^{NS}	3.9–8.3

Table 68.

Physical working capacity (kpm/min) before and after operation. Relative mean values, in per cent of initial value at ex. I, are given in italics.

Ex.	W_{130}			$W_{max \cdot perf}$			W_{lact}		
	n	M±SEM	range	n	M±SEM	range	n	M±SEM	range
I	68	465±19 *100*	71–787	82	537±18 *100*	133–900	76	469±16 *100*	193–841
V	55 *55*	434±17 *109.2*^{NS}	14–697	75 *75*	469±17 *87.4*^{xxx}	58–750	68 *66*	414±13 *89.7*^{xxx}	192–652
VI	60 *59*	494±21 *118.2*^{NS}	43–800	72 *72*	552±19 *103.6*^{NS}	200–900	69 *66*	463±17 *101.4*^{NS}	178–824

Table 69.

$HR \cdot \overline{BP}$ (beats per second · mm Hg) before and after operation. Relative mean values, in per cent of initial value at ex. I, are given in italics.

Ex.	n	M±SEM	range
I	81	290±7 *100*	156–421
V	71	247±6 *86.2*^{xxx}	140–394
VI	72	282±7 *97.8*^{NS}	140–393

TABLE 70.

Maximum observed lactate concentration in capillary blood (mEq/l), logarithmized, calculated value for lact in capillary blood at HR 130 (mEq/l) and calculated HR at lact in capillary blood = 5 mEq/l (beats per minute) before and after operation. Relative mean values, in per cent of initial value at ex. I, are given in italics.

Ex.	$lact_{max.\ obs}$			log lact 130			$HR_{log\ lact}$		
	n	M±SEM	range	n	M±SEM	range	n	M±SEM	range
I	76	7.1±0.3	3.3–12.9	76	0.79±0.02	0.53–1.41	76	119±2.4	65–166
		100			*100*			*100*	
V	69	7.3±0.3	3.4–20.1	68	0.82±0.02	0.51–1.32	68	115±2.4	64–170
	66	*106.5*^{NS}		*66*	*104.3*^{x}		*66*	*98.1*^{NS}	
VI	70	7.5±0.2	4.6–11.7	69	0.83±0.02	0.57–1.40	70	113±3.5	70–156
	66	*116.2*^{xx}		*66*	*107.8*^{x}		*66*	*97.7*^{NS}	

TABLE 71.

Values before and after operation: heart rates (beats per min) after 10 minutes' supine rest and after eight minutes' passive standing, maximum observed HR during exercise test and HR 10 minutes after exercise test. Relative mean values, in per cent of initial value at ex. I, are given in italics.

Ex.	HR_{rest}			HR_{ort}			HR_{work}			HR_{aw}		
	n	M±SEM	range	n	M±SEM	range	n	M±SEM	range	n	M±SEM	range
I	83	75.0±1.4	49–109	83	85.7±1.8	53–132	82	138.1±1.9	96–175	82	88.5±1.6	55–120
		100			*100*			*100*			*100*	
V	78	74.2±1.3	47–99	75	88.8±1.9	58–132	75	134.6±2.2	86–175	75	85.1±1.6	51–116
		100.4^{NS}			*104.6*^{xx}			*97.9*^{NS}			*96.5*^{x}	
VI	74	69.1±2.6	47–101	74	82.6±1.6	54–112	72	137.1±2.2	87–180	70	84.3±1.2	56–109
		95.2^{x}			*97.9*^{NS}			*99.0*^{NS}			*94.9*^{xxx}	

TABLE

Values before and after operation: arterial blood pressures (mm Hg) after 10 minutes' supine rest. minutes after exercise test. Relative mean values, in

Ex.	Systolic BP_{rest}			Diastolic BP_{rest}			Systolic BP_{ort}		
	n	M±SEM	range	n	M±SEM	range	n	M±SEM	range
I	83	149.8±2.0	105–195	83	85.7±1.2	40–120	82	140.6±2.2	100–195
		100			*100*			*100*	
V	77	137.1±1.8	110–195	78	76.0±1.1	55–100	74	123.5±2.2	85–185
	77	*92.0*^{xxx}		*78*	*89.5*^{xxx}		*73*	*85.9*^{xxx}	
VI	73	148.8±2.2	115–200	73	85.6±1.5	60–120	74	139.1±2.3	105–190
	73	*99.9*^{NS}		*73*	*101.1*^{NS}		*74*	*98.4*^{NS}	

TABLE 73.

ECG changes observed at rest, during an orthostatic test and during and after an exercise test before and after operation. With regards to ECG changes at rest only the most marked change of QRS or ST-T are listed for each patient. Under the headings ST_J depression at rest, ECG changes during an orthostatic test and ECG changes during and after an exercise test the series is divided into non-digitalis- and digitalis-treated cases. The incidence of ECG changes in digitalis-treated cases is given in brackets. The ECG findings were classified according to severity from 0 to 2 where 0 denotes a normal ECG finding and 2 a pathological ECG change. The total score per patient—i.e. the product of classification and incidence divided by the number of investigated patients—is also given.

	Classification	Incidence of changes at ex.		
		I	V	VI
ECG changes at rest				
Rhythm				
Occasional supraventricular extra beats	1	2	2	3
Occasional monotopic ventricular ectopic beats	1	2	1	0
Atrio-ventricular block, 1st degree	1	2	2	2
Atrial flutter or fibrillation	2	6	6	5
Total score per patient		0.22	0.22	0.20
QRS				
Incomplete bundle branch block (QRS< 0.12 csec) or abnormal QRS progression in precordial leads	1	4	3	3
Right bundle branch block	2	3	3	2
Left bundle branch block	2	2	2	2

72.

after eight minutes' passive standing, at the highest performed work load at exercise test and 10 per cent of initial value at ex. I, are given in italics.

Diastolic BP_{ort}			Systolic BP_{work}			Systolic BP_{aw}		
n	M±SEM	range	n	M±SEM	range	n	M±SEM	range
81	85.7±1.3	60–115	81	197.4±3.5	125–280	80	144.8±2.1	105–190
	100			*100*			*100*	
74	73.5±1.4	40–100	71	177.0±3.2	130–240	74	133.3±2.2	90–200
73	*85.3*^{xxx}		*70*	*84.1*^{xxx}		*73*	*90.1*^{xxx}	
74	83.9±1.5	50–120	72	197.0±3.3	120–255	70	141.6±1.9	100–180
73	*99.0*^{NS}		*72*	*100.3*^{NS}		*68*	*98.6*^{NS}	

Table 73 (cont.).

	Classification	Incidence of changes at ex.		
		I	V	VI
Borderline Q wave	1	6	6	6
Abnormal Q wave	2	4	5	6
$R_{V_5}+S_{V_1}\geq 35$ mm + VAT ≥ 5 csec	1	1	1	0
Total score per patient		0.35	0.38	0.40
ST-T (measured from preceding PR interval at onset of QRS in leads I, II, aVF or V_4–V_7)				
ST_J depression 0.5–0.9 mm	1	7 (4)	4 (2)	6 (4)
ST_J depression 1 mm or more	2	4 (4)	2 (4)	2 (2)
T wave flat or small diphasic, negative phase less than 1 mm (leads I, II, V_4–V_7)	1	4	2	3
$R_{V_5}+S_{V_1}\geq 35$ mm + VAT ≥ 5 csec + ST_J depression ≥ 1 mm	2	2	2	2
ST-T, total score per patient		0.42	0.30	0.33
QRS + ST-T, total score per patient		0.77	0.68	0.73
ECG changes during an orthostatic test				
Only the most marked change is listed for each patient				
Addition of isoelectric or slight diphasic T in leads II, III, V_5 or V_7	1	2 (1)	5 (1)	1 (0)
Addition of ST_J depression ≥ 1 mm and flattened T in leads II, III, V_5 or V_7	2	0 (2)	2 (0)	0 (1)

Table 73 (cont.).

	Classification	Incidence of changes at ex.		
		I	V	VI
Addition of ventricular ectopic beats from one focus	1	0 (1)	0 (0)	1 (0)
Addition of ventricular ectopic beats from two or more foci	2	0 (0)	1 (0)	0 (0)
Total score per patient		0.02	0.14	0.03
ECG changes during and after an exercise test				
Only the most marked change is listed for each patient				
Rhythm. Addition of				
frequent supraventricular ectopic beats	1	0 (0)	1 (0)	0 (0)
occasional ventricular extra beats from one focus	1	2 (1)	0 (0)	0 (0)
ventricular extra beats from one focus, coupled or in series	2	0 (0)	1 (0)	1 (1)
ventricular ectopic beats from two or more foci	2	5 (2)	2 (1)	1 (0)
atrio-ventricular block	2	0 (1)	0 (0)	0 (1)
Rhythm, total score per patient		0.19 (0.41)	0.12 (0.13)	0.07 (0.24)
ST-T.				
ST_J depression 2–4 mm during work	1	0 (2)	0 (1)	1 (0)
ST_J depression > 4 mm during work	2	0 (1)	1 (0)	0 (1)
ST_J depression 0–2 mm after work with ST_S horizontal or downward sloping	1	13 (0)	10 (1)	15 (2)
ST_J depression > 2 mm 4 min after work with ST_S horizontal or downward sloping	2	1 (0)	0 (0)	1 (0)
T wave flat or small diphasic after work when positive at rest before work	1	2 (0)	2 (0)	3 (0)
T wave positive or flat 4 min after work when negative at rest before work	2	1 (0)	0 (0)	1 (0)
ST-T, total score per patient		0.29 (0.24)	0.23 (0.13)	0.42 (0.24)
Rhythm+ST-T, total score per patient		0.48 (0.65)	0.35 (0.27)	0.49 (0.47)

TABLE 74.

Predominant subjective symptoms at discontinuation of exercise test. The figures in brackets denote the percentage numbers of all patients examined on the occasion in question.

Subjective symptoms	Examination		
	I	V	VI
No noteworthy symptoms	57 (70)	42 (56)	55 (76)
Degree of exhaustion: 1 light	14 (17)	0 (0)	8 (11)
2 moderate	34 (41)	27 (36)	41 (57)
3 severe	9 (11)	15 (20)	6 (8)
Local pain (hip, leg)	3 (4)	2 (3)	2 (3)
Muscular weakness or tiredness	8 (10)	19 (25)	8 (11)
Breathlessness	9 (11)	10 (13)	4 (6)
Chest-arm or chest-neck pain (judged to be angina pectoris)	5 (6)	1 (1)	2 (3)
Tremor, headache	0 (0)	1 (1)	1 (1)
Total	82 (100)	75 (100)	72 (100)

TABLE 75.

Influence of certain characteristics in preoperative state and per- and postoperative courses on changes in body weight, physical capability and associated parameters at examinations about 14 days (=V) and six months (=VI) postoperatively. Significances of differences between relative values for different parameters (expressed in per cent of preoperative value) are given, the different groups of patients being designated A and B for *a*bove average and *b*elow average, respectively, with regard to the factors specified in the left-hand column.

	Examination	d BW	d I_{musc}	d THb	d TBV	d $W_{max.perf}$	d W_{lact}	d HR · $\overline{BP}$	d $lact_{max.obs}$
Preoperative state:									
Age	V	NS	NS	NS	NS	NS	$B>A^{x}$	NS	$A>B^{x}$
	VI	NS	NS	NS	NS	NS	$B>A^{x}$	NS	NS
ECG	V	NS	NS	NS	NS	NS	NS	NS	NS
	VI	NS	NS	NS	NS	$A>B_{chd}{}^{x}$	NS	NS	NS
W_{lact}	V	–	NS	–	–	NS	$B>A^{xx}$	NS	–
	VI	–	NS	–	–	NS	$B>A^{x}$	NS	–
Peroperative course:									
Oxygenation	V	NS	NS	$A>B^{x}$	$A>B^{xx}$	NS	NS	NS	NS
	VI	NS	NS	NS	NS	NS	NS	NS	NS
Blood loss	V	NS	NS	$B>A^{x}$	$B>A^{xx}$	NS	NS	NS	NS
	VI	$A>B^{x}$	NS	NS	NS	NS	NS	NS	NS
Postoperative course:									
Temperature reaction	V	$B>A^{x}$	NS	NS	NS	NS	NS	NS	NS
	VI	NS	NS	NS	NS	NS	NS	NS	NS
Duration of catheter drainage	V	NS	NS	$B>A^{x}$	NS	$B>A^{x}$	NS	NS	NS
	VI	NS	NS	NS	NS	NS	NS	NS	NS

TABLE 76.

Values, M and (SD), for isometric muscle strength in various higher age groups. See text for further explanation.

Age (yrs)	n	Test no.									
		1_{dx}	1_{sin}	2_{dx}	2_{sin}	24_{dx}	24_{sin}	25_{dx}	25_{sin}	30	31
60–64	7	44.8	43.6	40.5	37.3	883	843	2643	2803	64.3	87.1
		(4.9)	(6.9)	(3.9)	(6.3)	(220)	(125)	(389)	(621)	(7.5)	(15.0)
65–69	10	43.7	43.5	39.7	37.8	870	810	2459	2741	62.9	81.5
		(6.8)	(6.3)	(5.6)	(8.1)	(158)	(154)	(570)	(935)	(16.9)	(23.4)
70–74	22	37.9	36.8	32.3	31.0	781	721	2268	2158	56.1	68.8
		(4.8)	(3.3)	(5.9)	(4.1)	(136)	(138)	(395)	(451)	(6.8)	(16.5)
75–79	12	36.0	34.3	29.3	28.5	679	624	1866	1841	52.8	66.6
		(4.8)	(4.8)	(5.4)	(5.5)	(139)	(105)	(334)	(376)	(8.6)	(15.6)
80–86	11	31.5	30.6	26.1	25.4	585	554	1826	1793	47.6	51.4
		(4.7)	(5.0)	(6.2)	(6.1)	(149)	(89)	(404)	(458)	(7.5)	(10.2)

TABLE 77.

Isometric muscle strength in essentially healthy males and in preoperative elderly patients with prostatic hyperplasia—the latter in italics.

Series	Age (yrs)	Test no.					
		1_{dx}	2_{dx}	24_{dx}	25_{dx}	30	31
TORNVALL (1963)[133]	19–20	–	–	1009	2010	62.1	65.4
BÄCKLUND & NORDGREN (1968)[10]	20–28	41.6	39.0	1188	2676	63.8	74.9
ASMUSSEN & NIELSEN (1961)[7]	65*	40.5	28.3	901	1190	53.1	72.3
RENCK (present study)	60–64	44.8	40.5	883	2643	64.3	87.1
RENCK (present study)	70–74	37.9	32.3	781	2268	56.1	68.8
RENCK (present study)	*60–86*	*33.6*	*29.0*	*639*	*1897*	*48.1*	*57.2*

* Height 170 cm

TABLE 78.

Relations between W_{lact} and THb and TBV before and after operation. Relative mean values, in per cent of initial value at ex. I, are given in italics.

Ex.	W_{lact}/THb			W_{lact}/TBV		
	n	M±SEM	range	n	M±SEM	range
I.....	66	0.71±0.02	0.28—1.24	66	84.5±3.0	29—145
		100			*100*	
V....	58	0.74±0.02	0.34—1.06	58	77.6±2.6	38—125
	49	*103.6*^{NS}		*49*	*91.3*^{xx}	
VI...	59	0.72±0.03	0.33—1.32	59	88.3±3.7	38—158
	51	*99.8*^{NS}		*51*	*104.0*^{NS}	

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